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APPLYING TIME DRIVEN ABC AT A HIGH-PERFORMANCE DISTRIBUTION CENTER'S LOGISTICAL COSTS

Master of Science thesis

Examiner: prof. Jussi Heikkilä and assistant prof. Teemu Laine
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TIIVISTELMÄ

Lauri Lehmus: AIKAPERUSTAISEN TOIMINTOLASKENTAMALLIN MUKAISTEN KUSTANNUSLASKENTAPERUSTEIDEN LUOMINEN TEHOKKAASEEN JAKELUKESKUKSEEN
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Tämän tutkimuksen päätutkimuskysymys oli, miten kohdistaa kohdeyrityksen jakelukeskuksen logistiset kustannukset. Kustannustenjaon tulisi olla prosessiperustainen ja kulut tulee pystyä kohdistamaan tuotteille, tuoteryhmille, valmistajille ja asiakkaille. Aikaperustainen toimintolaskenta oli kohdeyrityksen esivalinta kustannustenjakomalliksi.

Tutkimuksessa on sekä tarkkailullisia että interventionistisiä piirteitä. Tutkija on selvästi tehnyt intervention kohdeyritykseen, mutta samalla tarkkailullisia keinoja on käytetty. Ensimmäisessä osassa teoreettinen tausta on määritetty kirjallisuuskatselmuksen keinoin. Empiirinen osa on jaettu prosessienmallintamiseen ja kustannuslaskentajärjestelmän laatimiseen, joka perustuu prosessienmallintamisen tuloksiin. Malli luotiin ja validoitiin käyttäen useita eri metodeja. Tarkkailua käytettiin prosessien mallintamisessa. Keskusteluja käytiin esimiesten ja työtehtäviä suorittavien työntekijöiden kanssa. Alaprosesseja ja yksittäisiä osuuksia mitattiin manuaalisesti. Käytettävissä olevaa dataa käytettiin hyväksi. Tärkeimmät datat olivat transaktioista sisältöineen kertova sekö työpisteiden miehitetyn ajan seuranta. Data kuluista kerättiin kirjanpidosta ja sopimuksista sekä johdon arvioista.

Prosessit mallinnettiin ja ne jaettiin 14 alaprosessiin. Avainasiat ja parametrit huomioitiin. Prosessimallinnus loi selkärangan ja perusolettamukset kustannuslaskennan alkuunsaamiseksi. Kustannuslaskenta perustui aikaperustaiseen toimintolaskentaan, mutta teorian mallia muokattiin rohkeasti. Kolme todellista kustannuspaikkaa luotiin: vastaanotto & varastointi, varastossa pito sekä keruut ja lähetys. Keinotekoiset kustannuspaikat luotiin, tukemaan laskentaan todellisten ohella. Kaikki transaktiot prosesseissa todellisten kustannuspaikkojen sisällä vertailtiin keskenään ja arvotettiin kiinteillä kustannuskertoimilla. Kustannuskertoimet laskettiin projektin aikana käyttäen aikaperustaista toimintolaskentaa. Kapasiteetin kustannuskertoimet otettiin keinotekoisilta kustannuspaikoilta ja aika yhtälöt luotiin jokaiselle alaprosessille. Kaikki transaktiot arvotettiin tällä ajuripatterilla ja kaikki kulut todellisilta kustannuspaikoilta jaettiin transaktioille. Transaktioiden kulut voidaan kohdistaa vaadituille dimensioille.

ABSTRACT

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The main research question of this thesis was: How is Company X going to allocate the cost created by its distribution center? The cost should be process based and the model should be able to assign the cost to four dimensions: SKU, product group, manufacturer and customer. Time-driven activity based costing was a preset costing model by Company X.

The study has both observations and interventionist features. Researcher has clearly made an intervention to the company X, but simultaneously also observation methods have been used. In the first phase, theoretical background was created for the subsequent empirical phase. It was done by using scientific literature as source material. The empirical part is divided to process modelling and to cost management. The cost calculations are based on the findings at process modelling. The model was crafted and validated using multiple methods. Processes were observed. Hands on discussions with employees and management were used and time consumption of different sup processes and individual task were timed. Process data was available and it was used as an advantage. Most important operational data were transaction data including the parameters of each transaction and working hours measurements. The cost data was collected from accounting and contracts.

Processes were modelled and divided to 14 sup processes. The key factors and variations of each was noted. This created the spine to the costing model and the basic assumptions to the craft the drivers to the costing model. Cost calculations are based on time-driven ABC, but the model was applied greatly. Three actual cost centers inbound & storing, warehousing and picking and outbound were used. Artificial cost centers were used within those to create capacity cost rates. All transactions at processes inside actual cost centers are compared between each other with fixes intensity rates. The intensity rates are calculated during the project. These were done by time driven ABC. Capacity cost rates from artificial cost centers were used and time equations to each sup process were crafted. These created a driver pattern to value all transactions. All cost from the actual cost center are divided to weighted transaction and connected to needed dimension.

PREFACE

While my major is operations management and logistics, this Master of Science thesis project has been a jump away from the comfort zone. Completing it took quite a while longer than expected, but all together it has been educational and worthwhile journey to take. At least I have learned a lot about managerial accounting. Knowledge and ways to integrate operational management to cost knowledge and business intelligence might be a great strength in the future. I have had an opportunity to get to know a great well performing organization with great vision. The Company X is one of the best in it field. It was great to see and be a part of a startup of an ultra-modern distribution center.

"Most cases for time estimations knowing first digit and a good quest for the second is enough." (Kaplan & Anderson 2007)

I would like to thank professor Heikkilä and assistant professor Laine from support and counseling during this project. I would like to thank all my study colleagues and personnel at the university, who have been in touch during my years at the university. I own a great gratitude to my sister, since she was helping me with the language checking with this thesis. From to Company X I would like to thank all who have participated to the project especially ME, HH, SM, AU and MJ. Also special thanks to all warehouse employees, who have been really helpful and understanding towards the thesis worker wandering around, asking silly questions and measuring their work.

Paimio, 17.5.2017

Lauri Lehmus

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LIST OF SYMBOLS AND ABBREVIATIONS

ABC	Activity bases costing
ABW	Automated box warehouse
FM	Fast mover warehouse
IT	Information technology
LM	Logistics manager
MW	Manual warehouse
ODS	Od size warehouse
PO	Purchase order
PS	Production specialist
RMA	Return merchandize authorization
SL	Shift leader
TD	Time driven
TDABC	Time driven activity based costing
WMS	Warehouse management IT-system

1. INTRODUCTION

This Master of Science thesis is focused to create process and cost knowledge over subject company's distribution center inner logistic operations. Main subject is to create process knowledge for process development and create financial knowledge based on the process performance. The Financial performance is used to create profitability analyses and to back up business decisions. Study is focused on operational level and the area which is studied is narrowed to a single distribution center.

1.1 Motivation

In today's logistics and supplier customer relations management cost knowledge is essential. Customers are demanding more value added services from wholesalers, which is even increasing the impact of poor pricing, caused by poor cost knowledge on serving those customers. (Everaert et al 2008, s 173) Sales amount and revenue has been too close to measured and gross margins of different orders and customers have been left with less attention. Profitability of different orders have been seen vary a lot. Biggest customers are usually the most demanding ones and have best terms. Without deep understanding on organization's cost structure those might easily turn into negative relationships. (Shapiro et al 1987) In the end, gross margin is what the company will have regardless of the revenue. Knowledge of the profitability and making it easily measurable will be a key to better customer relations. As the old phrase goes:

"If we can define it – we can measure it;

If we can measure it – we can analyze it;

If we can analyze it – we can control it;

If we can control it – we can improve it."

In wholesaler environment where competition is hard and gross markings are extremely low, cost knowledge and management is vital to an organization. "Every penny is worth accounting for." (Varila & al 2007) Cost efficiency in logistics has become a necessity to manage in today's more global and streamlined world. (Everaert et al 2008, s 173). In a logistics survey 71 percent of replies ranked cost reduction/control as the number one concern in logistics (Cooke 2002).

1.2 Research problem, objectives and limitations

This study focuses on cost and process knowledge on Subject Company's distribution center. The Subject Company is referred to as Company X. It is a technical trader and whole seller in Finland. Products are information technology (IT) products or IT related products.

This study has one main research problem and three lower level research problems, which are supporting the solving of the main one. The main problem is:

- How is Company X going to allocate the cost created by it's distribution center?

Lower level research problems are:

- What is a reasonable level of accuracy when valid and real data over the costing units is provided but the costing tool is still easy to use?
- How the use of the model can be executed to make it simple enough for every day (or month) use so that it can still provide accurate information?
- How the processes can be modelled and measured to be able to make accurate cost management?

The object of the study is to create an accurate but easy-to-use cost modelling system to model the cost created by the distribution center. Objective for the cost modelling system is twofold. Firstly, it has to serve the business and financial departments in the company. The data is needed for dimensional profitability analyses by business managers and finance. Secondly, further development of the operations in the distribution center needs the knowledge on both real processes and the costs those are creating.

First object is to create cost knowledge over Company X's distribution center activities and allocate this to units caused those cost. Company X has an operational site a distribution center in Finland. Based on process and transactions the cost information should be possible to account to multiple dimensions by aggregating the created transaction cost data from to those dimensions.

- Product number (SKU)
- Product group
- Business unit
- Customer
- Manufacturer (Supplier)

Basically the lowest in the hierarchy is the product number, which always belongs to a product group and business unit and has one manufacturer, but multiple customers can purchase units of same product number. In the calculations, the product number is also the lowest level and the actual paths of single products are not tracked.

Second object behind the study is the company X’s need to refine their processes. The real time and process based costing model should provide information for decision making while evaluating different process improvement projects. Cost knowledge and further on cost knowledge over refined processes can be used in investment calculations.

In this thesis and in the project behind it with company X, we focused only to the cost created by the logistics activities (mainly warehouse). All other costs are left out from this examination. For example, functions directly touching products: purchasing, product management and sales & marketing are not involved in the examination. Overhead made by the management of the company are not involved.

This study aims no further than process modelling and cost allocation. Processes are modelled as they are (or are planned to be). No process improvements are specified in this study. Also cost allocation is made by how things are currently or after soon applied updates. Profitability analyses and actions are left to company X to perform. This study is focused on creating a cost management tool that is enabling those activities and creating valid and meaningful data to back up improvements and business decisions.

1.3 Research methodology and material

Aim of the study is not to create new generally valid information, but to solve a local problem by using and applying valid literature as an advantage. In this study, several research methods have been used.

The study has both observations and interventionist features. Researcher has clearly made an intervention to the company X, but simultaneously also observation methods have been used to more local subjects.

Data collection for this research will include observation and documented material from company’s own databases. Provided, collected and analyzed data will be in both quantitative and qualitative form. This kind of research method, where both quantitative and qualitative data is collected with multiple methods and analyzed in same research, is called as a mixed method research (Saunders et al. 2009).

Observation has been to get specific information on the processes of the company and performance of certain activities. For example, activities were timed to get better information on the time consumption. Observation and small scale in action interviews and discussions are done with employees in many organization levels. During the research project, many discussions and meetings with warehouse management and financial management of the company were done. Also, many observations were done, value how employees perform their tasks was. In addition, discussion with employees were done.

Company X documents and stores many kinds of data from multiple sources. The data could be used while performing the research. Logistic management system software stores variety of data to a database. This data source is so wide that the problem is more how to transform the data into information and how to even access and understand it, than gathering the data. Financial statements and existing cost pools created by the financial department were used with the help of financial specialists. Also, existing contracts with service and material suppliers were used to verify costs. Strictly confidential and protected financial and contract data is not directly presented in this thesis, but the information used is explained when it is used to make general understanding over the data usage to the reader.

1.4 Structure of the study

Literature review is divided into two chapters. In the first chapter is about process management and modelling. The main ways to study, evaluate and model the processes are illustrated. At the second literature review chapter (chapter 3) the background of costing models are investigated and further on the literature review is focused to selected model: Time-driven Activity based costing (TDABC). The history and foundations of

Chapter four is a sort information package about the subject company, which is in this thesis referred as Company X.

Also result chapters are divided to two. First (Chapter 5) the methods and results of studying and modelling the processes are illustrated. Next at Chapter 6 the ways and the findings while crafting the cost management system are provided.

Chapter 7 is a combination of summary and discussion. The implementation process with it limitations is went true. Summary of the core findings the cost is provided and how those are tested. Those form the driver pattern to cost assignment. At the discussion, the study findings are compared to literature once again.

Conclusions (Chapter 8) chapter specifies and summarizes the findings of the study. The first subchapter shows the summary of the study, following the implications of the study. Limitations of the study and ideas for future research are presented in the end of the chapter.

2. PROCESS MODELLING

To be able to create an accurate and functional costing method to an organization, it is vital to know what is actually happening in there. In other words, the whole complexity of organization's processes has to be studied and modelled. Sufficient process modelling and monitoring is needed in order to perform proper cost control, which is the way to track costs to cost objects and upper dimensions (Varila et al 2007). Process management and process knowledge is important in everyday decision making in operations management, and it also creates a base to strategic planning and development in an organization (Stevenson 2010 p.10), which was the other aim of this study. In this chapter, the keys and concepts of process and process modelling used in this study are illustrated.

2.1 Defining a Process and process organization

A process is typically defined as a chain of activities consuming organization's resources. Processes are purposed to produce value to customers. Customer set expectations, needs, goals and requirements to processes. Customer can be known or unknown and they can be external or from within the organization (where the process is made). Process is always a chain of activities, which are interrelated. It can be a simple one or very complex. Processes are usually repetitive. (Martinsuo & Blonqvist 2010, p. 5) Basic view over processes is illustrated in figure 1.

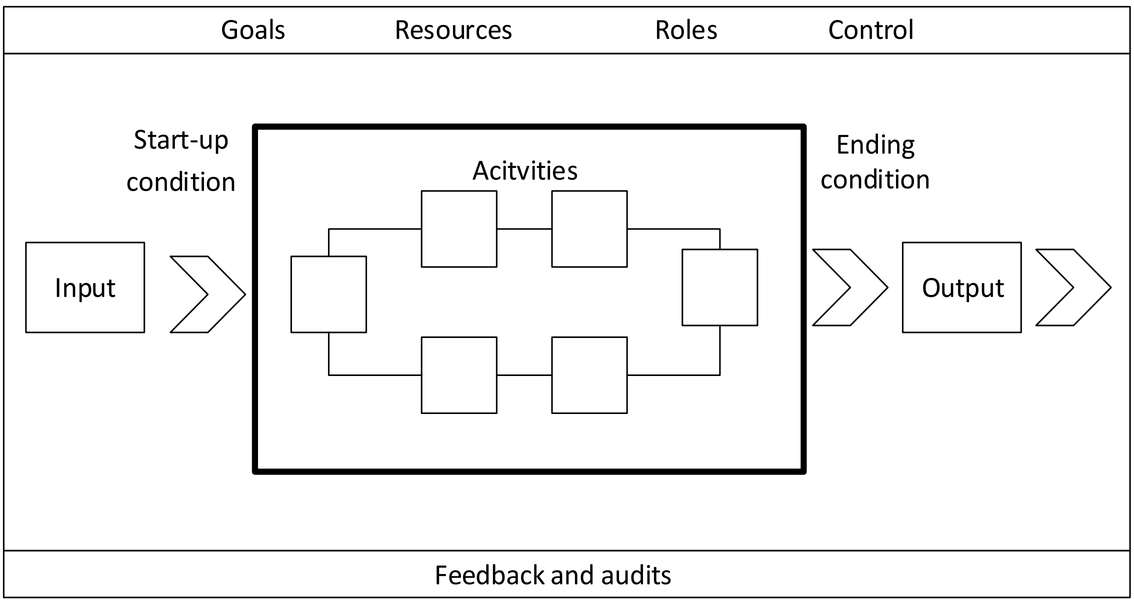


Figure 1. *Componets of a process. (Keto et al 2010, p 300)*

Keto (et al 2010) calls this view over processes as mechanistic conception of process. Processes have input and output and the process is intended to make a difference between those two. Consuming resources within the organization, such as raw material, workforce (roles), capacity, tools, capital, knowledge etc, make transfer from input to output. Martionsuo & Blonqvist (2010) see inputs as one of the resources consumed by the process and Keto (et al, 2010) sees those more clearly as inputs that are different from other resources consumed. Output can be a product, a solution, service, experience etc. (Martinsuo & Blonqvist 2010, p. 5 and Keto et al 2010, p299-300)

An organization can be viewed through it processes, but process view can also be the base of structure of the organizational design (Martinsuo & Blonqvist 2010. p. 6-7). Organizations can be designed purely on based on processes, by other criteria, or something between those two. Commonly processes are connected to organizational structure by their objectives and points where processes access resources from the organization. A process can go through boundaries in an organizational structure. It is common with core processes that all functions in a company are related to them. That creates a sort of a matrix structure where departments and processes form the two dimensions of the matrix. (Martinsuo & Blonqvist 2010. p. 6-7)

Martionsuo and Blonqvist (2010) identify four different types of distinctions to processes in an organization.

- Business processes and processes: Business processes create revenue and plain processes are not intended to create direct revenue, but are compulsory to perform.
- Core and support processes: Enterprise may have core processes and support processes, which serve the core processes.
- Main and sub-processes: Different levels of processes exist in the organization. A main and an amount of sub-processes. Sub processes appear inside main processes.
- Current and target processes: Current processes are the ones that are currently being executed and target processes are the ideal ones that should be or are planned to be.

Distinctions are not 100 percent unequivocal by literature and the point of view seem to have significant effect how the separation is done. Stevenson (2010) in the study book Operations management divides processes to three categories: Upper-management processes, operational processes and supporting processes. The book is, of course, mostly focused on operational processes. Those are seen as business and core processes of an organization by Martisuo’s Blonqvist’s distinction. Upper management processes are really high level and large processes, such as corporate strategy and whole demand and supply proses. All non-operational (not touching sold services or goods) are counted to support processes. (Stevenson 2010, pp.10-11) Both Keto (et al 2010) and Laamanen & Tinnilä (2002) see business process same as core process and plain processes are supporting those. Both determinations are mentioned in both titles, but stated to be equivalent. In addition, key and principal processes are said to be synonymous to these. (Keto et al 2010, pp 300-301; Laamanen & Tinnilä 2002, pp. 61-62) The performance of the core processes is crucial to an organization's success in the markets. (Laamanen & Tinnilä 2002, p. 61) Differentiation to core and support processes in industrial organization is illustrated in figure 2. It is an example of how processes in an organization can be divided to core and support processes.

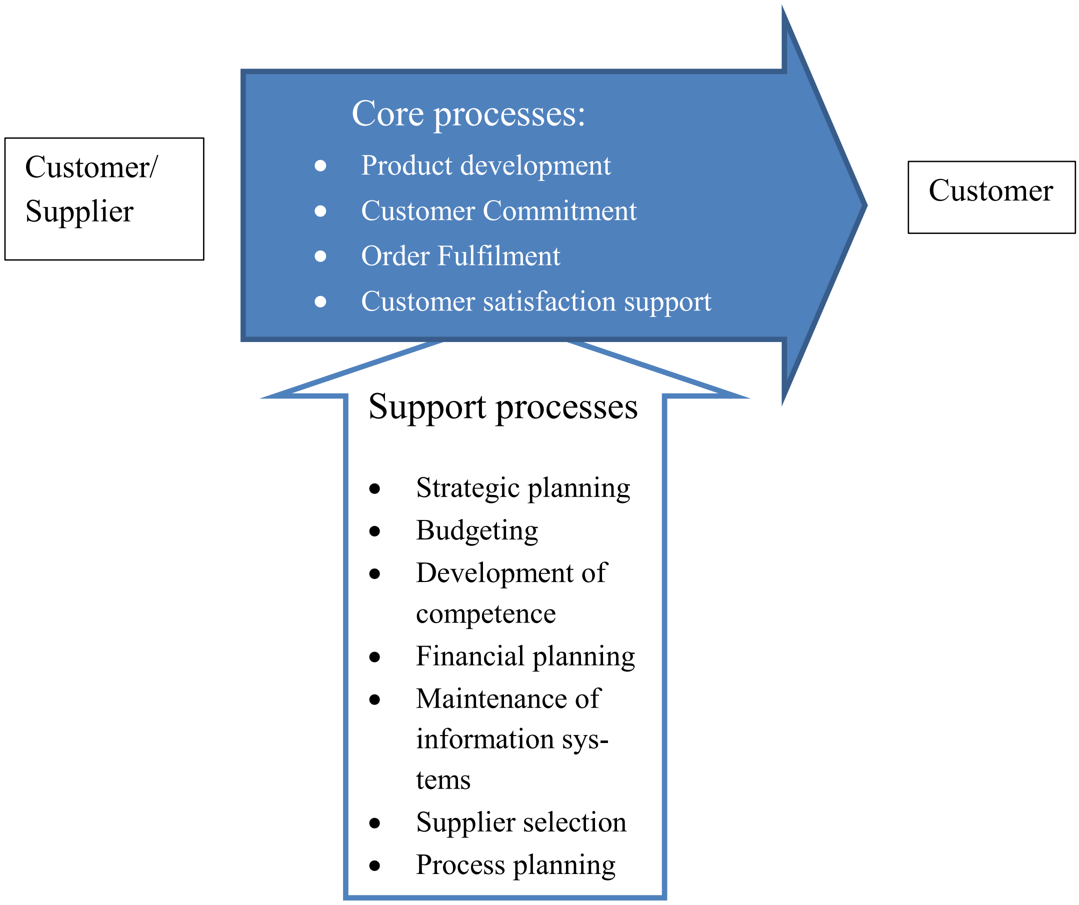


Figure 2. *Example of core and support processes in industrialized organization (Laamanen & Tinnilä 2002, p. 61)*

As in the beginning of the sub chapter and in figure 1 is said, a process consists of activities, but on the other hand those can be seen as sub processes, which may consist on smaller tasks. Processes can also have linked together within or outside the organization, creating a value chain or a value network (Maritinsuo & Blonqvist 2010, p. 11)

Keto (et al 2010) specify and compare different views over processes within a variety of authors. They tend to have different views and definitions over processes, process modelling and process management. The viewpoint of the author and the potential use of the model affect how those are defined. The length of the intended scope on applications differs the definitions. Keto identifies five different widely used definitions; those are listed in the table 1 by main author.

Table 1. *Different definitions of a process by author (Keto et al 2010, p 300)*

Reference	Process definition
Hammer, 1993	A business process is collection of activities that takes one or more kind of inputs and creates an output that is of value to customer
Davenport, 1993	A process is specific order of work activities across time and place. There is a beginning and an end, which are clearly identified into inputs and outputs, and a structure for actions between them
ISO/IEC, 1995	A set of interrelated activities, which transforms inputs into outputs
OMG, 2005	A Process is any activity performed within a company or organization. In BPMN a process is depicted as network of Flow objects, which are a set of other activities and the controls that sequence them.
Whitehead 1929	The world is a process which is the becoming of actual entities (or actual occasions)

Those views are different, but also have a lot in common. Whitehead in 1920's has described entire world as one process that divides smaller and smaller sub processes. Others are more 'bottom to top' built models.

Process variation is always present and it must be acknowledged while modelling processes. Variation in processes can be divided into two categories: variation without a reason and variation with a reason. Stevenson (2010) lists four reasons of variations as listed in table 2.

Table 2. *Reasons of variety in processes (Stevenson 2010, p. 11)*

Variation	Cause of the variation
Variety of goods and services being offered	The greater the variety of goods and services, the greater the variation
Structural variation in demand	These variations, which include trends and seasonal variations, are generally predictable. They are particularly important to capacity planning.
Random variation	This natural variability is present to some extent in all process, as well as in demand for service and products, and it cannot be generally influenced by managers.
Assignable variations	These variations are caused by defective inputs, incorrect work methods, out-of-adjusted equipment, and so on. This type of variations should can be reduced or eliminated by analyses and corrective actions.

Stevenson's view is really operationally orientated and basically focused on industrial environment, but it can be easily applied to warehouse environment. It is focused to minimize unwanted variation and understand it all. Random fluctuation can be modelled with statistic tools as normal deviation (Stevenson 2010, p 480). In cost allocation and management point of view it is crucial to understand which variation is standard and caused by a reason and which is random fluctuation.

In this thesis, a process is defined mainly as Keto (et al 2010) and Martinsuo & Blonqvist (2010) have described it. There are other definitions, but this has been chosen to this study. It will serve the purpose of the study and fits well with the process modelling and the costing model described later.

Apart from process description above, one applied term from field of computer sciences and commerce is adapted to this thesis. In commerce, transaction is an exchange of goods or services between buyer and seller involving three components: seller, good or service and buyer. (BusinessDictionary.com 2016) In computer science transaction means, single unit of work processed and it is generating a change in a database. The unit processed is created by an act in the real world. (Butterfield & Gerard 2016) This is applied to use while a single process is performed once. For example, one pallet is stored to the warehouse. It has three components, the inbound area where the pallet was, the pallet itself and the warehouse were the pallet is stored. In addition, the warehouse management system's database is changed. This is helping the reader to understand when the talk is about a single action and when an entire process or activity. This was widely used in the subject company and during the thesis project.

2.2 Modelling

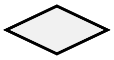
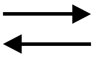
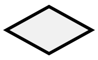
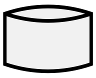
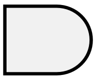
There are many ways to understand what belongs to process modelling. Keto (et al 2010) define process modelling simply as: “A Process model is an explicit description of a process” (Keto et al 2010, p 301). Laamanen & Tinnilä (2002) states, that a process should be defined with five items:

1. **Customers**: their needs and requirements (Also other stakeholders). How they will use the output.
2. **Mission**: which are the critical success factors and how the performance is measured
3. **Input, output and services** (also including how the information managed)
4. **Process flow chart**: activities and visualization
5. **Responsibilities:** Which are the most important roles and teams. Which are the most important decisions and actions. Which policies and guidelines should be used?

These illustrates that process modelling or defining the process. It is not just drawing a flow chart about activities concerning the process, but it should be done with quite deep understanding on all the matters related to the process. Keto (et al 2010) describes process modelling always tasks and situation related. The person doing the modelling (modeler), the goals of the modelling and the process itself have a relationship between each other and are affecting on the results and the way of doing the process modeling. For example, the modeler has some relations and intentions to the wanted results (=goals) from process modelling, which may effect on the modeling on unwanted way. (Keto et al 2010, p.302-203)

There are also many different methods to do process description, which are usually seen as visualization, but can also be a literal description. Not a single method has achieved to be a standard one. Martinsuo and Blonqvist (2010) state that four most commonly used are process flow chart, flow diagram, task matrix, and textual instructions. Despite various describe methods; the symbols used in process mapping are usually similar. In table 3. Process mapping symbols are presented as Martinsuo & Blonqvist are describing those.

Table 3. *Symbols used in process mapping (Martionsuo & Blonqvist 2010, p 15)*

Symbol	Meaning
	Start or finish
	Activity or process
	Material or informational flow
	Decision point
	Document
	Information system / data storage
	Inventory
	Data
	Delay

Martionsuo & Blonqvist (2010) claim that those are the most commonly used ones and based on other literature symbols are the same or similar.

Examples on distinctive styles on process mapping are illustrated on figures 3 and 4. Figure 3 is an example of process flow diagram and figure 4 is an example of process flow chart, which is also known as swim line chart (Laamanen & Tinnilä, 2002).

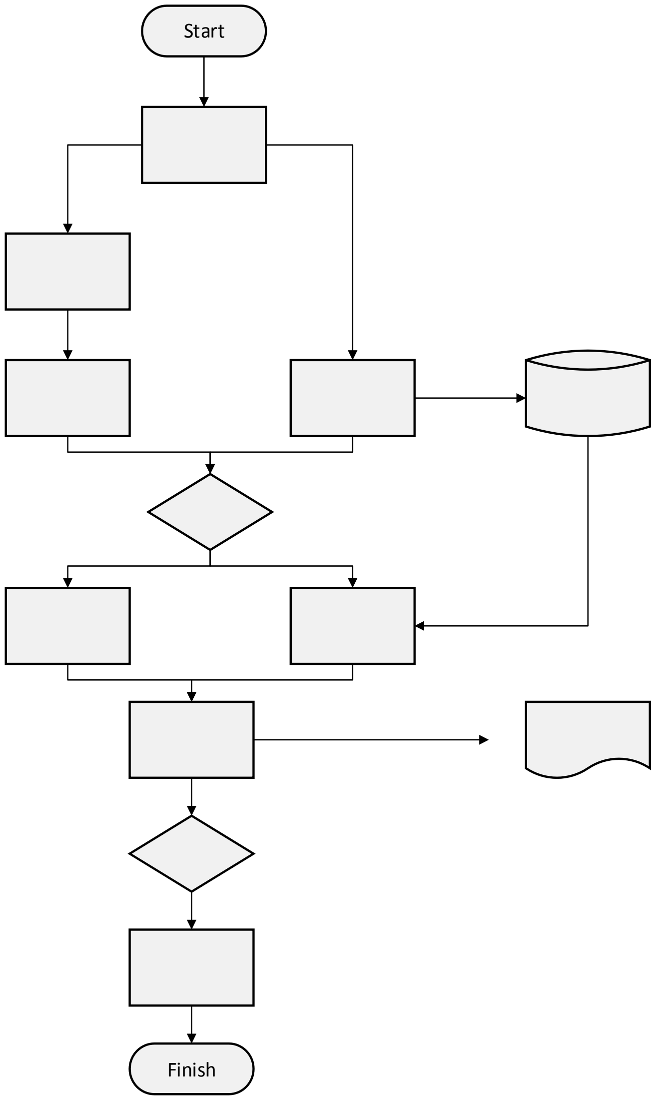


Figure 3. *Example of a process flowchart (Martionsuo & Blonqvist 2010, p 16)*

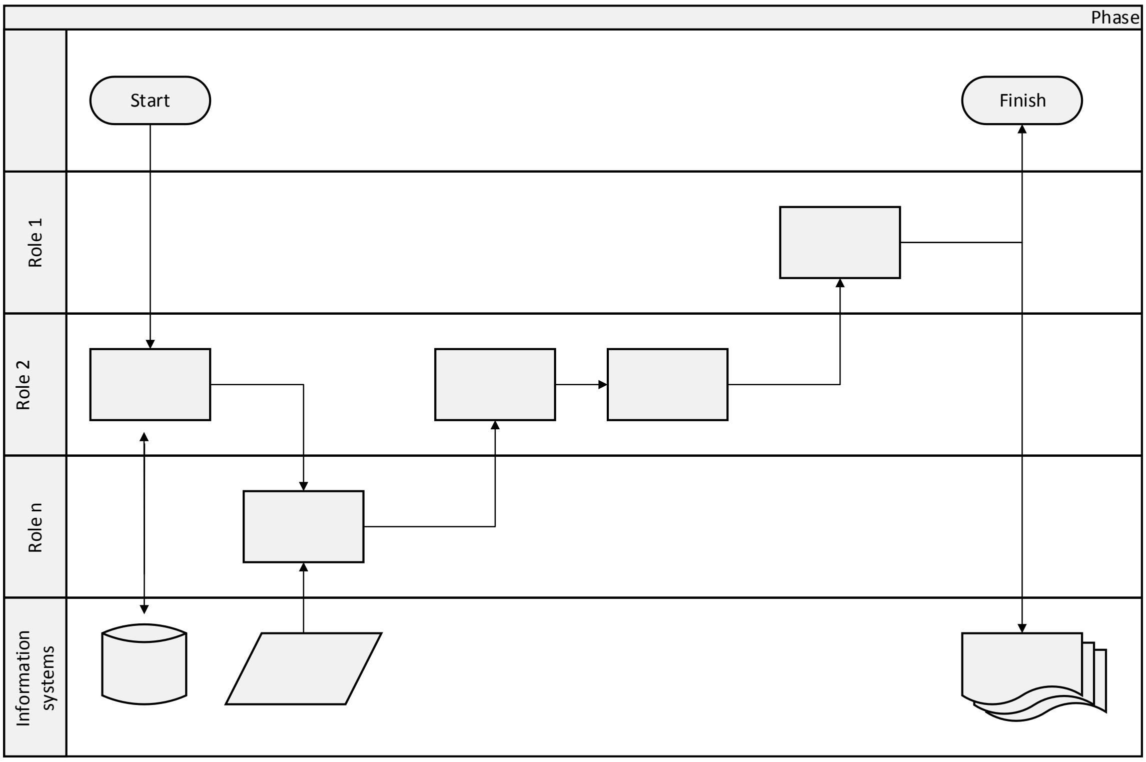


Figure 4. *Example of a process flow diagram aka swim lane diagram (Martionsuo & Blonqvist 2010, p 16)*

Both process flow chart and diagram have a good visual presentation on processes and timeline of activities should be clear. On the other hand, neither does not provide very detailed information on sub processes or other matter regarding processes, only the symbol and a name of a sub process is telling the reader, what is happening in this pace. These can be supported by or be supporting textual presentation over the process. These both answer to the fourth bullet listed in the beginning of this sup chapter, stated by Laamanen and Tinnilä (2002). To answer the other bullet, more literal approach on process modelling is mostly needed. Table 4. is an example of task matrix, which can be seen as a sort of combination of flow diagram and literal review.

Table 4. *Example of a task matrix (Martionsuo & Blonqvist 2010, p 17)*

	Phase 1	**Phase 2**	**Phase 3**	**Etc.**
Role 1	Task, which Role 1 should complete in this step, OR outputs which must be generated before a certain decision point or milestone			
Role 2				
Role 3				
Role 3				
Role 4				
Etc.				

Process modelling can be chaotic and difficult to follow, while processes usually are complex. Mapping with certain style and good naming system will make it more systematic and easier to follow by others. Naming should be logical and may base on the output or task. (Martionsuo & Blonqvist 2010, p 12 & 17) In some cases it is not relevant to model every detail of the process, but to see the big picture of the processes. On the other hand if the process is really stable and process modelling should lead to working orders, the modelling should be really specific. (Martionsuo & Blonqvist 2010, p 12 & 17)

Laamanen & Tinnilä (2002) brings up a definition to process map, which is focused to describe the main process or processes of the organization. A process map is an advanced level of presenting the big picture of organization's business model and revenue logic. It can also be seen as marketing brochure or senior management tool to illustrate the whole organization. The vision, values and core resources can be added with the main process and most notable sup processes. (Laamanen & Tinnilä (2002)

Important part of the modelling is to be honest and face the imperfection in the organization. Actual processes, which are currently running in the organization should be modelled, or at least to be separated from the target processes. It is important to understand the cap between target and current processes and to go further to process improvement. (Martionsuo & Blonqvist 2010, p 17) Salomäki (1999) states that in process improvement it might be use full to model even five different processes.

1. Processes according to current instruction
2. Actual process
3. Target process with no limits (not realistic: no budget, system or other limitations)
4. Realistic target process
5. Actual process with actual improvements

That creates a lot of work, but also a vital view, how the performance is actually behaving. (Salomaki 1999, p353) In cost management view, modeling the actual processes is vital, since those are creating the actual costs. On the other hand, this creates an opportunity to compare the cost created by target processes to cost created by actual processes and decision makers can analyze if the improvements are reasonable.

Key factors to check while doing process modelling.

- Processes are needed to identify. Important is to distinguish the processes by the interaction with customers and by the hierarchy in the performing organization.
- Process modelling aims for deep understanding of the process and its attributes and process description (verbal or visual) is a part of it.
- The actual processes are modelled or there is understanding that non-real life (improved or target) processes are modelled.

3. COST ASSINGMENT MODEL

Accurate cost assignment and cost knowledge is vital in managerial accounting. In more general it is vital in financial management and in even more general in the executive decision making. (Neilimo & Uusi-Rauva 2005, p33-34) This study is focused on the managerial accounting. Object of the study and the main research problem is to create an evaluated system that will handle the cost assignment with products, product hierarchies, customers and suppliers. Time driven activity based costing was pre-set as the costing model to this study. This literature review part will shortly go true the ground where the time driven activity based costing was born and how it differed from previous models and how it has been applied, since its introduction about one decade ago. To research and apply the knowledge from accounting and cost management world, some basic principles must be defined.

As industrial environment and organizations have grown and evolved during the history, also managerial accounting and cost management have tried to face the realities in the field. More complex organization, process and production environment have created a demand for more complex costing methods. (Neilimo & Uusirauva 2005, p 13) On the other hand complex costing methods are resource demanding. Complexity of cost calculations can follow up the complexity of the computing situation exponentially. Getting accrued enough results with less effort would be reasonable and desirable. (Everaert et al 2008, Atkinson et al 2007 and Kaplan & Anderson 2007)

3.1 Background to cost management

Matching principle is the key at cost assignment. It means, that all costs should be assign directly to their cause. Cost unit should be responsible to all the costs it is creating and no more. That is often a hard or even impossible task to perform at 100 percent accurate, but keeping it as a target it is possible to make cost management relevant. When matching principle is honoured, it is meaningful and fair to use the results. For example, compare the profitability of product lines or single products within the organisation. Cost knowledge can be used as a tool with pricing. On the other hand, depth of calculation should be in reasonable level. The reason to perform cost management is not to perform cost management, but to aid the whole organization to better results. (Suomala & al. 2011, p. 90)

Cost (or accounting) object is an entity to which the costs are computed. A costing object can be for example a product, a product line, project or an organizational unit. (Atkinson et al 2007 p. 31.) With accounting objects complex real life situations are turned into calculations and mathematics and further to numbers (Champman 1997). Accounting object represents the base units which are analysed in the given context. It can be analysed via the monetary values, but also with non-financial values. (Laine 2009, p 65-66)

Using product cost (or other cost object) information inside the organization usually have two divided board categories: planning and evaluation. A simple example for planning is to use the product cost knowledge with pricing and further on with budgeting. Evaluation purposes can be such as comparing processes to produced products in or outside the company. Bonus systems for employees can be attached to cost evaluations. (Atkinson et al 2007 p 31.)

3.1.1 Process and Job order costing

Job order and process costing methods have had been popular, simple and effective ways to allocate cost, when cost objects are simple. (Suomala et al 2011, pp 106-107)

Process costing is effective when all the products are similar and need almost equal amount of resources. Basic example is a power plant which produces only electricity. Output is certain measurable amount of electricity and all the cost can be divided with that value in megawatts, so calculation gives amount of capita per megawatt. (Suomala et al 2011, pp 108-109)

Job order costing can count in assorted products and variation in the processes. Costs are strictly divided to direct and indirect cost. Direct cost are most simply direct material and labor cost. Indirect cost, such as occupancy, are calculated to the cost objects with overhead cost. Indirect costs are firstly assigned to cost centers, which will have aa certain overhead cost to products or services using it. An individual job order needs to be tracked as one costing unit and the overheads are tracked to it. (Atkinson et al 2007 p. 85) Overheads to products are calculated and added if the product (or service) uses this cost center or not. (Suomala et al 2011, p. 109) The simplest way to compute the overheads is to assign the overhead costs of a cost center by the share of the direct cost each costing object uses (Martinsuo et al 2016, p 261). If the total direct costs are 100 and costing unit one is using 4, four percent of indirect cost are computed to costing unit 4.

Job order and process costing are good when the environment and costing objects are stable. Those both are created with assumption of stable and predictable markets, long product cycles, large batch sizes and indirect cost are a minor part of the cost structure (Varila et al 2007). When those assumptions are no longer valid, more detailed and more variable accounting is needed. In traditional costing cost are assign based on units sold or produced, order sizes do not affect the costing, which is usually against matching principle. Customers with frequent small orders create more overhead cost than those with few large orders. (Everaert et al 2008, s 173).

Since processes, product, product mixes and whole organizations became too complex and inaccurate to model with job order costing, more complex and detailed costing methods where needed. In today's organization structures can be really complex and indirect costs might be 80% or more (Everaert et al 2008, p. 173).

3.1.2 Activity based costing

Activity based costing (ABC) came popular at the late 1980's. Limitations of process and job order costing became too obvious at more complex situation. It was common that product quantity and complexity became too great to handle with traditional costing methods.

ABC costing is a twofold process first cost created by resources are allocated to activities and cost at activities are allocated to costing units such as products. Resources like direct labor, raw material, indirect labor, occupancy are the actual source of costs of the organization. While job order costing had a separation to direct and indirect cost, it is not used with activity based costing and all cost are streamed true activities. (Turney 1994, p96)

At the first phase the resource cost are assign to activities by the resource drivers. Resource driver is telling which and how much of resources one activity is using. The second page is to assign the activity costs from activities to costing units. Here activity drivers are used. (Turney 1994, p 96-100) Atkinson (et al 2007) divides the activity drivers to three categories:

- transaction
- duration
- intensity

This creates ABC's two-fold process to assign the costs. Turney (1994) describes and illustrates activity based costing as two-dimensional process with process view and cost assignment view. The activity is in the middle where those two dimensions are joined together. This so-called CAM-I cross is illustrated in figure 5.

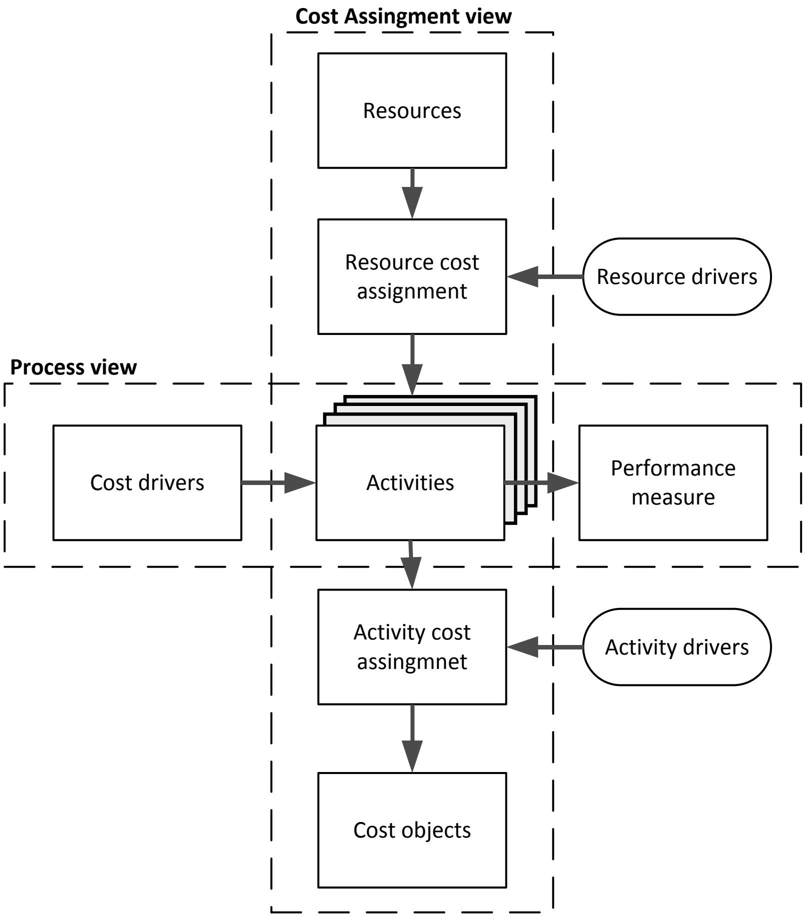


Figure 5. *CAM-I cross (Turney 1994, p96)*

In the Turney's two dimensional model the economic monetary related cost assignment view is directly linked to non-monetary process view. The process performance and measuring it is directly combined with the financial performance, unlike with job order costing. The process view performance is not just the physical level of creating outputs, but also how customer and total quality expectations are filled. The process view should provide the actual source of need why a certain activity is performed. This creates more information to the executives in the organization. Cost can be directly combined with the outputs form the organization and to customers or suppliers (internal or external) creating the need to perform those series of actions. (Turney 1994, pp. 82-93)

This method is providing a lot of data form organization and its processes, but does not automatically solve any problems. It is supplying information for decision makers at the organization. Allowing them to make the decisions based on the process related cost information. As can be seen at the Turney's model, cost calculations are not an individual part of managing the company, but those are strictly related to all other task in the organization. Even a term activity based management is used to represent managing style where activities and activity based costing is used to manage the organization. (Neilimo & Uusi-Rauva 2005, pp 143-144)

Increased complexity is one of the major downfalls of activity based costing. When real life complexity increases, the complexity of cost calculations is increasing exponentially, if the modelling accuracy is kept in similar level. Exponential increase is caused by the two driver levels. This was the reason why Steven Anderson interested about developing a simpler, but still (as they claim) accurate enough ABC-like method. (Kaplan & Anderson 2007, pp 5-9)

3.2 Basics and a brief history of Time driven activity based costing

Time driven activity based costing is relatively new model. It was introduced in 2004 by Robert Kaplan and Steven Anderson. Kaplan is Harvard university professor and has been one of the major author, not only concerning activity based costing but, also cost and performance management in general. Anderson has been his student in 1990's. Together they firstly published article to Harvard business review in 2004 and in 2007 a book "Time-driven Activity-based Costing, a Simpler and more Powerful Path to Higher Profits". Those two publications are the grounded theory for time driven activity based costing and the theoretical base cost assignment on this research. Most of the information from the 2004's article is also provided in the book, so references to the article are seldom seen. Of course, other publications are used to criticize and expand Kaplan's and Anderson's view on TDABC and cost assignment in general.

The key idea in TDABC is to make activity based costing simpler, but still be able to assign all cost by the matching principle. Simplification is made with cost drivers since time is the only cost driver as the name of the model says. No activity drivers are used and time can directly assign cost from recourses to cost objects. All performed work is measured by time consumption and the consumed time is valued as resource in the company. No other cost factors, allocation levels nor cost polls are needed. (Kaplan & Anderson 2007)

TDABC can assign resource cost directly to the cost objects. As with normal ABC resource cost needs to be allocated to activities and afterwards activity cost can be assign Research methodology to cost objects. Allocating resource cost to activities has turn out to be very complex and work demanding. That all can be skipped by using time as one solid driver. (Kaplan & Anderson 2007, p 23) On the other hand the time driven ABC can adapt modern complexity of organizations and processes. Matching principle should not be harmed. (Kaplan & Anderson 2004)

Time is used as primary driver since most resources such as equipment and personnel have capacities in time. In other words, there is a maximum time some machine or personnel is available to work in one month (or day, quarter etc.) In some cases, time is not a valid driver at all. For example, when assigning freight charges to costing units on board. It is possible to use for example weight in that part of the calculations (Kaplan & Anderson 2007, p 23)

Calculating with TDABC is basically simple. Calculations need two factors: capacity cost rates and process times. Operations which are under calculations needs to be divided to functional and measurable cost centers. All resources, each cost center is consuming, must be allocated. Cost are divided with time, which is the normal effective maximum capacity of the cost center. In many cases minutes are good calculating base. That gives the capacity cost rate per minute to each cost center. (Kaplan & Anderson 2004) Process times are the time which is needed to provide or handle a product, a unit, a service, a transaction etc. If the action under inspection has many alternatives and variation on transactions it uses, time equations are needed. Time equations are an efficient way catch complexity and variations by adding or decreasing time assigned to one transactin. Costing system considers what is really happening in transaction and how much performed work is needed. (Kaplan & Anderson 2007 p 23-41)

TDABC use transaction data provided by enterprise resource planning systems (ERP, CRM or equivalent data system) as an advantage. Accurate data is vital to TDABC (Kaplan & Anderson 2007, p 24).

Varila (el al 2007) are using time as a driver in their research with Finnish electronics wholesaler. They are using more traditional ABC and compare which driver in ABC is best with reasonable resource consumption. They conclude that duration is a superior driver in ABC at their study. They are close, but still they are not applying Kaplan's and Anderson's TDABC model. Next year Everaert et al (2008) (including Steven Anderson) published a study on Belgian flower care products wholesaler. The target company had already started to apply TDABC as they day to day business. The study was based on Kaplan's and Anderson's TDABC, but also findings in Varila's (et al 2007) study. Afterwards other authors have studied time-driven activity-based costing in multiple business fields.

3.3 Estimating process times valuing the cost drivers

This first principle is simply just evaluating how long it take to perform a certain activity for example production run, customer service or order processing. In theory it is really simple, but complexity of operations creates complexity also to the cost calculations. Kaplan and Anderson (2007) uses order processing as on example. It is basically receiving a customer purchase order (PO) and reacting on it and simply process time is how long it takes for one sales rep to do this.

Organization usually have different type of customers, which send different kinds of purchase orders. Those characteristics make processing times to vary. Although usually those POs consist of same kind of elements. To understand the added complicity of characteristics time equations are needed, those strip down the processes to sub processes which may (also in quantity) or may not acquire in an order processing. These characteristics may appear in many levels (sub sub… processes). In one main process, there might be tens or hundreds of sub processes

Time equation is a sum function where all the characteristic of the process are included. All are measured with time and existing one's ad certain amount of time to equation. For example, if the order is from new customer it can take 5 minutes to establish a new customer to organization's data base. This 5 min is added to time equation and in finally it adds the cost equivalent of 5 minutes of capacity time of that function. Because of the amount of sup processes time equations can be really long, but still those are simple to calculate when times of each sub processes are evaluated. (Kaplan & Anderson 2008, p 27-28)

Processing customer order is a sub process to Market and sell action and it can contain these listed sub processes in tree levels, making totally five levels of processes in the organization.

1. Market and Sell
    - 1.1. Process customer orders
        - 1.1.1. Create customer file
        - 1.1.2. Obtain rate quote form sales
        - 1.1.3. Create transportation document
            - 1.1.3.1. Domestic
            - 1.1.3.2. International
                - 1.1.3.2.1. Prepare customs form
                - 1.1.3.2.2. Prepare shipper's declaration
                - 1.1.3.2.3. Arrange for consular clearance
        - 1.1.4. Create document to describe special services or handling
        - 1.1.5. Prepare document for dangerous goods handling

Time equation can be as illustrated in table 1. It is basically a sum formula on the events that might happen in the activity.

Table 5. *Time equation formula (Kaplan & Anderson 2007, p.28)*

Order processing time (minutes) =	10 +5 (if new customer)
	2 x number of line items
	4 x number of rate quotes
	+{(if international order) +2 if customs form +5 if shipping declaration +10 if consular clearance}
	+ {if special services} (5 {if rush order} + 10 if credit hold + 2 if hazardous material

Time equation is a sum calculation of the quantity of the defined sup processes that are currently in use. In the example listed in the table 5 there is some lines that need to be multiplied by the quantity and some that will only occur once. With this equation, standard processing time for domestic 4 line item order, with no special handling or services takes 18 minutes [10 + 2*4] to set up the order.

Varila's (et al 2007) used actual process times measured by ERP system, which is of course is accurate when measurable. With those it is hard to capture the complexity and variations of processes, like time equations can do. In Varila's research complete process time were measured actual or estimations when ERP-data was unavailable. Everaert (et al 2008) find out that time equations catch complexity of wholesaler's processes in effective way, while Varila stated that using entire process time's variety is a major problem. In conclusion Varila comes up with new question "if time drives cost, what drives the time?" Time equations might not be the ultimate answer to that, but seems that those will cut the problem to smaller pieces and make it more understandable.

At time equations and measuring time it is visible that time driven ABC has been evolved from traditional ABC. Time as a driver with time equations has elements from all tree possible drivers on ABC. Duration driver is involved while measuring time, but also that can been seen as intensity driver, since same resource is used, but with different intensity, which is measured in minutes. On the other hand, all the time equations can be seen as transactions, since if task will trigger lines in the equation. In that way one action can contain several different transactions that will all have some intensity that is measured in time.

3.4 Capacity cost rates

The other phase of Time driven activity based costing is to identify capacity cost rates. Those are assigned by time unit supplied by the cost center. Simplest it is to assign how much one minute of work costs in one cost center. If we stay with the order processing how much are all the cost created by the function divided by how many minutes they perform. Cost are created, when resources are consumed within the organization.

In Kaplan and Anderson's (2007) model resources are supplied by organization's departments. If the departments are homogenous enough those can be straight used as cost centers when valuing capacity cost rates. Departments are homogenous, if the resource mix consumed by the processes is similar. If departments perform processes that consume different resource mix those should be divided as individual cost centers. That's is called process view to capacity cost rates. (Kaplan & Anderson 2007, p.49,50,71)

In process view the relations to the other processes are crucial. Processes can be a sub process to each other, one can be after the other or processes can be side-by-side with each other. One cost unit can go true all or just some of the processes in the department. As an example, Kaplan and Anderson illustrate surgeon room and warehouse. In an surgeon room, there is two processes: surgeons with and without cardiac procedures, since cardiac procedures need very costly equipment's and it is not needed with any other type of surgeons. That's why those costs are assign only to cardiac surgeons. In warehouse the process of whole department is split to smaller sub processes, since those consume resources in diverse ways. Sub processes form logical entities such as outbound, inbound storing and picking. Work performed in those is different and it is reasonable to measure it differently. (Kaplan & Anderson 2007, p. 49-51)

Demeere (et al 2009) has a bit different approach on cost pools. Different processes consume different types of resources and time equations can be created by sum of those different cost pools. The study was about hospital costs and cost pools where

- Labor (two levels)
- Facilities (two levels)
- Material
- Machinery

Certain activity could consume simultaneously resources (time) from multiple cost pools, creating the total capacity cost rate. (Demeere et al 2009, pp 299-301) This can also be seen as an alternative to Kaplan's & Anderson's time equation.

Resource consumption should be assigned by the actual capacity that can realistically be supplied, not theoretical maximum capacity that can be performed by workers or machines. Kaplan and Anderson (2004) stated that usually actual capacity is with workers between 80 to 85 percent and with machines a bit more. (Kaplan & Anderson 2004) They (Kaplan & Anderson 2007) continue to use customer service department as an example, where the order processing is included. The measured output is clearly the pace of employees, but in other cases it could be machine hours or other. Actual capacity is measured by time when employees are available to perform the actual work, like process customer orders or do credit checks. (Kaplan & Anderson 2007, s42) Rest is consumed by arriving, departing, breaks, communication and trainings etc. In case of machines hours the unusable capacity is usually allocated downtime by maintenance and unallocated breakdowns. (Kaplan & Anderson 2004).

If department is the unit calculating capacity cost rates all the cost created by the department must be allocated in one pool. After that the whole sum can be divided with time unit (minute, hour, etc.) All the cost associated by the department must be aggregated to the calculation, including technology, equipment, compensations to employees and their supervisors and the cost of corporate staff supporting the department. General cost or in other words supporting processes must be assigned to those cost centers that are consuming those resources. (Kaplan & Anderson 2007, p 41) Kaplan and Anderson divide cost to six categories: employees, supervisors, indirect labor, equipment and technology, occupancy and other. If the cost center is a process within the department this step is similar, expect all the cost should be dealt with process level. (Kaplan & Anderson 2007, p49)

3.4.1 Frontline Employees and supervisors

Personals usually take a great share of total costs. Frontline employees and supervisors are directly in touch with operations or processes, which are being measured. These are usually simple to assign since employees and their supervisors usually work in one department at time. All the cost form employees must be taken on to accounting: salaries, payroll taxes, medical and other insurances and earned pension benefits. (Kaplan & Anderson 2007, p42)

3.4.2 Equipment costs

Equipment and technology cost include operating expenses and expenses owning the equipment's. Short term costs are maintenance and running costs. Machines may need daily checks and for example oil or some other consumable supplies to perform the work tasks. (Kaplan & Anderson 2007, p43)

Machines may be really costly and create depreciations expenses or equivalent rental expenses. Also, if machines are owned the cost of capital must be included. ABC-costings depreciations can be equivalent as in financial statements or different. In most cases calculations are more accurate in management accounting than in official the financial statements. Deprecations usually deal only with the original purchase price, but within ABC residual income can be used to provide more accurate accounting with capital cost. Also, inflation and value of new similar machine can be used as value base on accounting, since the acquisition price years before might be well below (or above) than the price of similar machine today. (Kaplan & Anderson 2007, p43)

3.4.3 Occupancy costs

Occupancy cost is the cost created by supplying space to for departments. Simply occupancy cost rate should be the total costs divided by the square meters and then multiplied by how many square meters a department uses. If some departments use special areas such as clean rooms the extra cost of those should be assigned to those departments. The occupancy rate per square meter should include share of buildings depreciation, utilities, maintenance (to occupancy, no machinery), housekeeping sand insurances. (Kaplan & Anderson 2007, p44)

3.4.4 Corporate staff and support expenses

Many functions in company do not directly touch products or services to customers, but provide vital resources to frontline functions, which touch customers. Human resources or IT are usually this kind of back row functions. Actions done by those are essential to organization, but time spend on those is not directly in touch to orders, products or services to customer. The caused cost and time consumption can be assign to front line processes in various methods. (Kaplan & Anderson 2007, p45-46)

In figure 6 an organizational chart form general resources to cost objects (in this case products) is illustrated. All the processes consume general resources as labour. Departments have been divided in two: support and operating. Operating departments are the ones that are directly in touch with cost objects which can be also services. The key in this subchapter is how the cost of support departments is assign to operational departments. (Kaplan & Anderson 2007, p45-46)

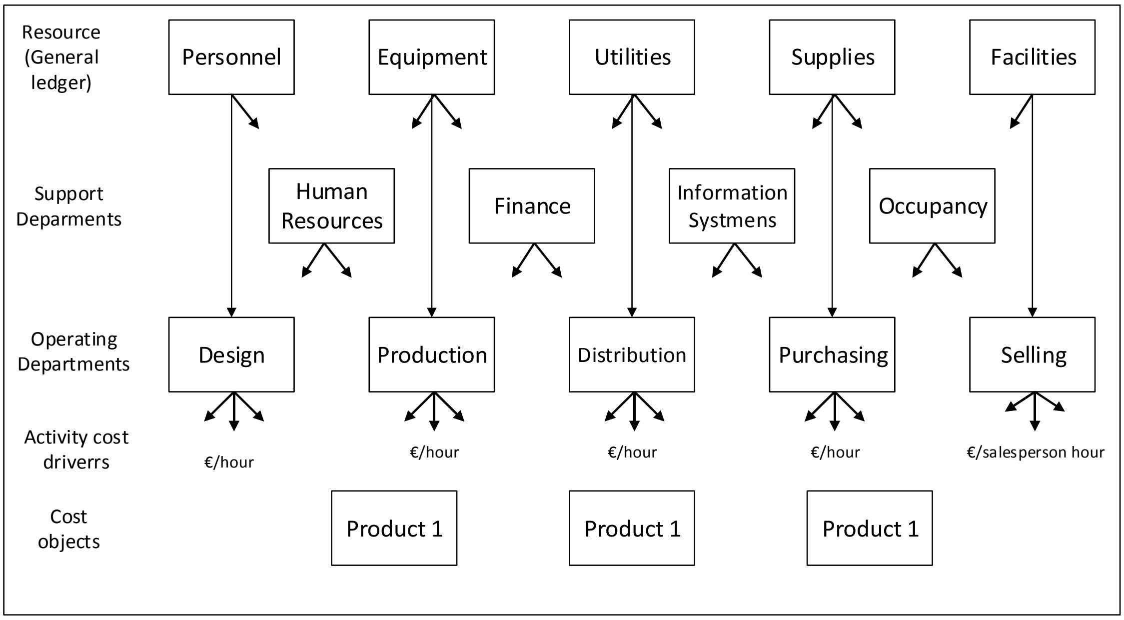


Figure 6. *Resource expense flow to support and operating departments. (Kaplan & Anderson 2007, p 45)*

There are many ways to assign indirect cost and that basically comes back to fundaments of managerial accounting. These costs can be a major part of total cost, so it is not irrelevant to have deeper analyses. Some organizations use percentage rate according some driver to assign these costs, which is like job order costing. Driver could be percentage of sales or employee's quantity, direct labor hours etc. in the frontline department. Allocations should present economic reality and be reasonable accurate. Being too strict does not provide added value, but being too inaccurate won't have satisfying results and may provide misleading information. Added percentage is not usually the best way and do not respect the matching principle enough. Kaplan and Anderson suggest that TDABC can be used to assign supporting cost created by the corporate staff and support function. Matching principle is the key and TDABV should be able to deal with that. Principles are the same as with operational departments, but in this case customers are the other departments. (Kaplan & Anderson 2004)

Kaplan and Anderson (2007) stated that it is not relevant to assign all corporate expenses back to the operational departments, if the expense has no link back to specific division. Meaning that the cause of the service, is not in the operational department, but in somewhere else. These can be costs like running the headquarter or doing the corporate level financial statements. The cause making corporate level financial statement is not in the operational departments, it is needed by the law. Those are said to be fixed and operation variety or level doesn't affect directly on those. Also the size of the supporting departments makes the calculations more meaningful. That does not mean that most of the corporate level activities can be left away from deeper assigning, but to focus on the most relevant and affective ones. (Kaplan & Anderson 2007, p 46)

3.5 Strengths of TDABC and action

Making usage out of time equations is one of the key advantages comparing traditional ABC. Basically in TDABC all units are valued in time and no others are needed. No activity dictionaries are needed as in traditional ABC, which needs all the characteristics to be dealt as separate activities. That's why complexity increases exponentially in traditional ABC, but only linearly in TDABC. (Kaplan & Anderson 2007, p 28-29)

Process time valuations should be simple and appropriate. It seldom creates added value to be too strict and aim for perfection. Kaplan and Anderson states: "Most cases for time estimations knowing first digit and a good quest for the second is enough." and "TDABC strives to be approximately right than preciously wrong." (Kaplan & Anderson 2008, p 26) That is reasonable since there could be thousands or more actions that are modelled and measured. Also time equations and model in general is easier to update, if the complexity is not too great.

TDABC may need to be supported by elements from ABC or from traditional volume based costing. Barret (2005) stated that functions are not enough homogenous to value only by time. As an example, research and development or marketing functions work performance is heavily related to task they are currently performing. Actual effectiveness is hard to measure only by time. In those cases, time is not enough to value the work performance and calculations are slipping towards normal activity based costing, since other values or compensations are needed. (Barret 2005)

Varila (et al 2007) studied similar retailer's warehouse environment and mainly it's picking activity. As already mentioned in previous sub chapters**Error! Reference source not found.**, Varilas'(et al 2007) study compared different cost drivers on traditional ABC and their accuracy on a picking process of an automated plastic box warehouse. Study findings where that duration of the activity is a superior cost driver over transaction or insensitivity.

Varila (et al 2007) state that creating a duration based activity drivers is more complex than transaction based. Because of that the popularity of duration based was lower, even thou it could lead significantly better results. On the other hand, with modern ERP-systems, which can store tremendous amount of data over transaction, that data base can be turned into an advantage. Item's movements can be tracked in the warehouse or in factory floor. System can even directly tell the actual time that unit spent in the measured location. In Varila's study organization, ERP system could track how long warehouse boxes stayed in picking stations. (Varila et al 2007) As counter opinion to that, the ERP-system have certain inputs and those maybe do not present the actual situation in the work floor.

Notifying unused performance is built-in at TDABC, while traditional ABC is assuming that all actions are used at 100 percent utilization. Process time or time equation will have a total sum of used time at the end of the month and unused capacity is leave out. This capacity is not assigned to any cost unit. (Tse & Gong 2009) This may even lead to better management of supplied capacity or problem having the unused capacity, if it is must to have.

Everaert's (et al 2008) target company collet the detailed cost data created by the TDABC-model monthly and aggregated per customer, product and supplier. With better cost knowledge, the target company noticed significant troubles and opportunities in their business. They were able to spot the profitable and unprofitable customers and product lines. With this knowledge company got a reason and right to perform actions to improve business.

It has been noticed that it is easier to specify the absolute time rather than percentage of total working hours to perform some activity. There are many approaches to estimate the process times for each activity.

- direct observation
- accumulating time required from a set of specific activities
- interviewing or surveying employees
- utilizing existing process maps
- leveraging time estimations from other similar cases within company or target industry

When the system is crafted many of these could be used simultaneously or other can be used to validate and adjust the oncoming cost calculation. (Kaplan & Anderson 2004) Financial and operational validation is needed, after the model is crafted) At the financial side the model should allocate all the costs from the resources used all away to cost objects. On the operational side the sum of the modelled time consumption should be same as the actual time consumption. (Kaplan & Anderson 20107, p 75-77)

The key criteria to evaluate the cost calculations to craft drivers to assign resource cost to costing units are:

- Using time driven ABC as theoretical framework
- Calculations are based on measured processes
- Honoring the matching principle
- It is possible for company X to implement the model, use it with ease and have results from using it

These criteria are somewhat in contraction with each other. Focusing one might lead neglecting other(s). All should be measured together and the final evaluation can be seen not a sum but as a multiplication of the results from each factor. Failing one leads the total value to zero.

4. COMPANY X

Company X is a technical trader, wholesaler and importer of technical goods. The company belongs to European wide group. The whole group is noted in one stock exchange in Europe. Company X is located in Finland and is fully owned by the group. Main business of the whole group is to be a technical trader and sub companies in the group represent similar business nationally. The group effects on day to day business, but Company X is really independent within the group and the group is more like holding company behind the national companies. The revenue of the Finnish company is some hundred million Euros.

Importing and delivering technical goods is the core and traditional volume business of the company. Cloud technology, information based and value added services have become new sources of revenue. The Company has one operational site, a logistic center, and two office locations in Finland. As stated in the introduction, this study focuses only on the operational site and its inner logistics where physical goods are handled inside the warehouse/distribution center.

Customer base is divided to business to business (B2B) and business to customer (B2C) segments. In B2B segment customers are focused to serve their customer’s needs with IT solutions. Company X provides the hardware to those. B2C customer base consist smaller and larger customers from one men IT stores to nationwide retail chains. In logistics cost management point of view those segments are not greatly different. Both segments have larger and smaller orders and direct shipments to customer’s customer are used.

A big trend have been that customers focus on their core activities and storing IT items usually is not one of those. During time order quantities have become smaller and intensity of the orders have increased. Customers order directly to demand and do not have large stocks. Many nationwide retailers don’t anymore order to central warehouse, but to each specific store individually and maybe even every day. In this environment wholesalers needs to be agile and picking and sending need to be efficient. This creates both challenges and possibilities. Also the role of extra services is increasing. Serving customer more completely creates possibilities to extra revenue, but also creates more work. Key to success is how to ground this price of service to customers and make it reasonable as mentioned by Everaert (et al 2008).

Organization chart in the warehouse has three to four levels depending the counting style. Logistics manager (LM) is the head of the warehouse and reports to chief operating officer. Below the LM are shift leaders (SL), which are responsible for all warehouse and logistical activities while in charge. Below the SLs there are production specialist (PS) and basic floor employees. Production specialist are senior employees that has special knowledge about certain process or activity in the warehouse. They also have some supervisor tasks and responsibilities on the employees. Production specialist are acting as vice shift managers. They are also in charge of training new employees. Most of the employees are from the house, but mainly on peak seasons hired workforce is used to reach higher capacity. Some employees are more specialized to specific activities and some can move easily from one activity to other.

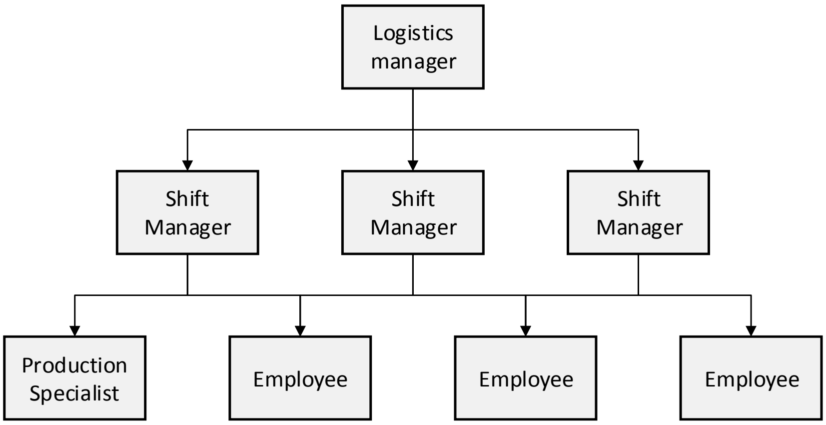


Figure 7. *Organization chart in the company X's warehouse.*

5. ESTIMATING THE PROCESSES IN THE COMPANY X

This chapter provides an analysis over the processes, which will be measured in cost calculations in the next chapter. This chapter provides basic information and modelling over the processes in Company X.

Operational site that is the subject of this study is a distributor's warehouse / distribution center. Main process is to get the material from suppliers, store those and send sorted shipments to the customers. Different items are stored in different warehouse types, depending on physical abilities and volume of the movement.

Like in most warehouses, the Company X's subject warehouse has inbound, storing, warehousing, picking, packing and outbound. Material has a logical flow from inbound to outbound through some checkpoints, and all sub processes are visible. All listed sub processes have sub sub processes and different paths within the process, which will be discussed more in the sub chapters of this main chapter. These processes are also the base of the costing units on the cost calculations. The time consumption analyses with time equations are also made within and/or combining these listed processes.

Warehousing area has been divided to four different sections by movability and physical abilities of items. Most movable items are stored in fast mover warehouse (FM). Items are stored in pallets on floor. Pallet places are very limited. Manual warehouse (MW) is a traditional shelf warehouse for standard pallets and it is about 10 meters high and has 5 to 6 shelves. Only the two lowest shelves are available for picking (if not full pallet picking) and others are reserve locations. Odd size warehouse (ODS) is for items that are too big or in some other way impossible to store in the other sections. ODS got mainly items which are bigger than standard EUR-type (1200x800mm) or FIN-type (1200x1000mm) pallet or the weight is especially heavy. Small items are stored in automated plastic box warehouse (ABW). Box's inner size is about 56x36 centimeters and max load height is about 40 centimeters. It is quite fast and easy in use, but on the other hand the complex mechanical automation system has been a large investment and requires much more maintenance compared to other warehouse areas. Main process is modeled in appendix 1.

In the warehouse, all items are stored to a platform either on a pallet or in a plastic or a cardboard box. Cardboard boxes are only used after picking. Those platforms are kept in locations, which can be in a warehousing area or outside it. The warehouse is controlled by warehouse management IT-system (WMS). All the information from the warehouse is stored to it and are going through it. It tracks where the items are, optimizes the work flow and gives work orders that employees and automation execute. All transporting and picking orders are going true WMS. It optimizes the work load and combines it to the optimal usage of the warehouse locations.

At the warehouse many processes, which are visible and measurable, can be identified. The warehouse has been divided to three logical main processes that contain different variation of sub and variant processes.

1. Storing the goods
2. Warehousing
3. Sending the goods to customers

Inbound can be seen as the first process and it is followed by the storing to the warehousing locations. Warehouse got four different areas with basically two different storing platforms: pallets or plastic boxes. All the processes before and after must be implemented to those options. That means two kind of storing processes, one for pallets and another for the plastic boxes.

All the storing areas can be seen as individual processes, while the items are kept in the shelves. After warehousing, five different types of picking and sending processes are identified. Size of the shipment, product abilities and warehousing location affect the picking process and those are done by different working methods and machinery. After being picked, some of the parcels go through box closing and consolidation process and some go directly to the outbound area. After outbound, there is a transportation process to customer or other destination. Below are listed all sub and sub sub processes.

1. Inbound
2. Storing
   2.1. Automated box
   2.2. Full pallet
3. Warehouse areas:
   3.1. Automated box warehouse
   3.2. Fast mover
   3.3. Manual
   3.4. Od-size
4. Inner transportations
5. Picking
   5.1. Automated box picking
   5.2. Fast mover picking
   5.3. Picking from manual or od size warehouse
      5.3.1. Group

        5.3.2. Direct parcel
        5.3.3. Whole pallet
6. Box closing & consolidation
7. Outbound & pallet consolidation
8. Transport

In total that would take 14 processes that will be gone through in this chapter (upper levels containing lower levels are not calculated in). Many of them share similarities as can be seen in the names as well. Still, all sub processes in different areas differ in action and more importantly by the means of cost calculations and cost pools. The first 13 are directly handled in the warehouse by the Company X and the last one is done by external transportation companies. All of these can be seen as business and also as the core processes. Those are directly in touch with the products sold to customers and creates the added value done by the distribution center.

The company has also two other large processes in the distribution center: pre-installation and return merchandize authorization (RMA). Pre-installation has one large office room and is focusing to adding parts or software to sold products. It can be seen as value added service to company X's customers. RMA is focused to inspect and carry on warranty claims made by the customers. Both are in touch with other processes mainly with outbound and inbound. Both can be seen also as business processes, since they are directly connected to products and create value to customers. Of course, RMA is needed due to the bad quality among sold products. There is no revenue from customer side, but the manufacturers involved are funding the process. Pre-installation takes SKUs they use from the warehouse via normal picking and it is seen as normal customer in the picking process and at the cost modellings. It just has a delayed shipping, compared to normal shipments. Inside activities and performance of neither of those are involved as a subject of this study and therefore they are discussed no further.

In the warehouse, there are also some support processes, which create costs. Basic cleaning is done by outsourced cleaning company, but some effort must be placed to maintaining the warehouse, mainly fast mover, manual and od size warehousing areas. At outbound cleaning and removing the waste (extra packing material etc.) can be seen directly related to core process. Corporate level management and support functions can also be seen as support processes to the warehouse, but those resources and their effects are not included to this study.

5.1 Inbound and storing

Inbound is the first touch to products coming from the suppliers. Usually the supplier is also the freight arranger and payer. In any case the inbound (nor outbound) freight cost is not an object in this study. Inbound and storing process is illustrated as flowchart in figure 8 and afterwards described as text with the sub processes.

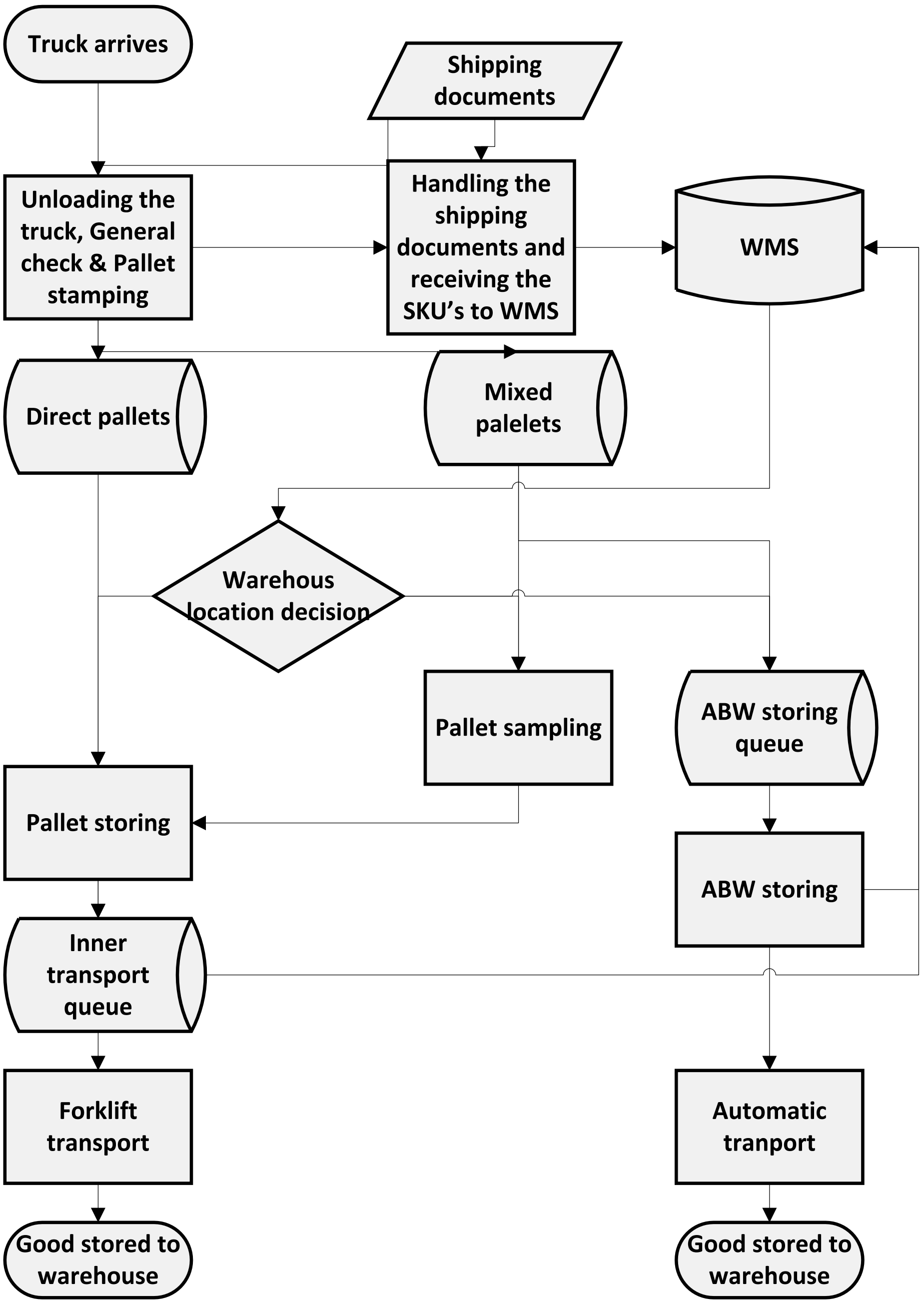


Figure 8. Inbound and storing process

Incoming trucks are unloaded in the loading docks. First pallets are pulled to warehouse feeding areas and stamped with pallet stamps to connect those to shipment and purchase order(s), supplier and so on. General check for transportation damages and missing pallets/parcels is done. Most of the suppliers do freight consolidation, so one incoming shipment may contain material from various purchase orders. All the lines of the shipping documents must be manually read as received to ERP system. When received to ERP, an signal to the warehouse management system is sent and those items can be stored.

Since warehousing is basically done a product number by product number (SKU by SKU) the incoming goods must be sampled individually by product number. In other words, one platform is carrying only one product number (SKU) at time. After the shipping documents are handled and when the originally shipped pallets are lying on the feeding area and the sampling can be stated. All the items that are going to automated box warehouse are taken to own pallets and to the ABW storing area. All the ones that are going to manual, fast mover or od-size warehouses are individually sampled to pallets.

This is the most challenging process to model since there is plenty of variation and unknown. Products on the incoming pallets could have been organized in any way by the supplier. Some incoming pallets contain only one product number and are in other ways standard and can be directly stored. Others need to be re-palleted if the original pallet is smaller than standard, mostly this is a case with products that are almost a pallet size (like multifunctional printing machines) and sent in smaller pallets to have less transportation cost. Those are put on a standard pallet at stores like that. Some pallets containing only one product type need to be broken down because pallets are originally too high. In that case, the top most products must be taken to a new pallet. Most of the incoming pallets are mixed containing many products. Those need to be rearranged from the original to new pallets one SKU at time, in most cases the pallets also contain products that will be stored to ABW. This is much more workforce- and time consuming than direct pallets. The hardest are mixed pallets that contain a lot of similarly packed product that are hard to identify from each other.

Incoming pallets can be one of the types listed below:

1. Direct pallet
    a. Direct pallets
    b. Repalleted
    c. Split
2. Mixed pallets

Time consumption of the sampling process is really hard to model, since there is basically no information from the pallet mix of the incoming shipment. Different shippings have a lot of variation within one supplier, product group, or even single SKU. It is extremely hard to model within time and different shipments even product by product how those are shipped by the supplier. Also the employees at inbound are handling numerous tasks and multiple inbound shipments simultaneously, so automatic measures of their working hours compared to stored items is not good either. This will be further discussed and analysed in the next chapter.

Simultaneously with the sampling, the warehousing area decision is made. Decision is quite simple and is illustrated in table 6.

Table 6. *Warehouse decision hierarchy.*

1. If the product do not fit in a normal pallet	ODS
2. If the product is set to be a fast mover.	FM
3. If it can be fit in an ABW box	ABW
4. If none of the previous (normal pallet)	MW

Employee reading the lines in will make the decision by the size of the product and the quantity of the products. If the product is a fast mover or not has been preset to system and the system will inform the employee and it will be taken to fast mover location. A large incoming shipment of SKU small enough to fit to ABW, could be divided between ABW and manual warehouse. The space in ABW warehouse is more critical than in a manual one, so only a portion will be stored to ABW and the rest will go as a reserve to manual. The reserve will be restored to ABW after the first portion is running out.

Pallets containing small items are taken to ABW feeding queue, and pallets going to manual, fast mover or od-size warehouse areas are stored to warehouse management system and taken to manual (also fast mover and od-size) feeding area. A reach truck will pick the pallet up and transport it to warehousing location. A reach truck driver scans the pallet label and the warehouse management system tells the location where the pallet should be stored.

Automatic box warehouse has its own storing stations, where the storing is done and the stored box are immediately taken to warehouse by the automation system. There is one employee per station and he/she takes the items from the pallet to the warehouse box and simultaneously stores the items to warehouse management system. Boxes can contain different SKU, if those items are small and have low quantity. Space dividers are used within the box. All the boxes have identification number with bar code. Material is physically stored to a box and the material number and box's identification number are given to the warehouse management system. Employee puts the box to a conveyer and the automation system takes care of the box and the material inside. It takes it to the warehouse location and to the picking station when needed.

5.2 Warehousing and picking

This is the basic and maybe the main function of the warehouse, keeping the material well organized at stock. Every item is stored in a platform: a pallet or a plastic box and that is in some warehouse location. Those form the connections to the warehouse management IT-system, which creates the picking orders etc. Picking is so closely related to the warehouse area type, that those are discussed in this same sub chapter.

As said before, warehouse has been divided to four different areas. ABW and Fast mover have their own picking methods (AWP-picking and FM-picking). Manual warehouse have three different picking methods: group picking, direct parcel picking and whole pallet picking. From od-size warehouse items are basically picked by whole pallet picking, but direct parcel picking is also possible. In process based view od-size storing and picking are like those in manual warehouse, od-size warehouse can be seen as an expectation or one location in manual. It is discussed in same subchapter with the manual warehouse.

Items can be sent away in multiple sized cardboard boxes and on standard or nonstandard pallets. If the shipment is really small on physical volume, the items are picked to a plastic box (similar to those used as platforms in AWB-warehouse) and changed from plastic box to small cardboard box at packing station.

General from all picking methods is serial number reading and protection of specific products. Some products need to be protected with bubble air before placing to an order box. Process is simple, employee wraps air-bubble wrap around the products and secures it to place with tape. Those items really have a need for protection. Customers will send those back to be inspected, if found out to be shipped without protection. The protection only concerns tiny amount of all products. They are mainly warehoused in the ABW.

Serial number (or other item specific identification) reading is done while picking. It is done if the product number is set on a list needing the reading and the number is presented in the product. Need is determined by product manager. Basically, products with higher value must have serial numbers. Serial numbers must be read on approximately half of the SKUs, but low value ones have a dominance on picking quantities. Some products have two different serial numbers that both need to be scanned. Serial number reading is done with a bar code scanner or by hand if the scanner can't recognize the number. Usually the reason is wrapping around the product and serial number is presented only directly on the product (not on the package). That is a rare situation. Warehouse management system tells the employee to read the serial number every time when needed. Both sub processes bring extra work to the picking process and those need to be modelled to the cost calculations

There is a possibility to multisource products in different warehouse locations, but it does not make a difference on cost calculation aspect, since warehousing cost will be based on time spend in a warehouse location and picking and storing costs are based on transactions which have on input and output.

5.2.1 Automatic box warehouse

In the automatic box warehouse the platforms are plastic boxes, which are about 600x400 mm in bottom and 200 in height, but a bit taller items can be loaded in. That creates a simple limitation of the volume of SKU's stored in this warehouse. This is heavily automated and can be described as a machine that stores plastic boxes. Employees handle only reading SKU's in and taking them out at the picking stations. Rest is done by the automation, which is controlled and measured by WMS.

Automation system controls the boxes during the warehousing and optimizes the usage of warehouse space. Most movable items are put into locations close to picking stations and those with low movability are put to locations further away. All on all the automation is effective while making internal transportations. On the other hand, the system needs to be maintained and it is suffering from failures from time to time. Those will lower the capacity or even prevent storing or picking.

Density of storing locations is high per square feet of floor compared to other warehouse types. Of course, volume of one location is much smaller compared to 1 to 2.5-meter-tall pallet locations in manual warehouse.

Picking is done at specific picking stations. At the picking station, there is one place for the box that comes from the warehouse and multiple locations called order slots for boxes which are filled and sent onwards. Even though picking stations are human operated, the automation system has a huge impact and basically only the moving of right quantity of items from warehousing box to another box is done by human. The automation brings the warehousing boxes from the warehouse to the station and gives picking orders via a pc in the station. Employee takes the given number of products form the warehouse box and places those to a new box in precise order slot. Empty boxes are provided to the station. New cardboard boxes are pre-build by a machine and automatically transported to the picking station. While picking the right amount the employee also reads the serial numbers and does protection when needed.

When one order box is filled with all material needed from AWB-warehouse, the employee pushes it to a conveyor belt behind the order box location. If the box is physically filled up before the order is completed, the full box is sent onwards and a new one is taken. The automation transports it to the next step which is fast mover picking or packing stations if no products are needed to the box from fast mover picking.

5.2.2 Fast mover

Fast mover is a specific area of the warehouse designated for the most movable products. Products are kept in pallets and picked from them. Most of the products are quite small and cheap, some have higher value, nevertheless all have a high volume of movements true the warehouse. Movability is measured on total quantity of sold items, so both the quantity of the lines and the strength of the lines can put a SKU to fast mover. Fast mover warehouse was created because storing (and also picking) high quantities and high physical volumes of items to automatic box warehouse is time consuming.

Area consists of two reserve shelves, like the manual warehouse, and the picking area between those. The picking area has very limited space, for only the most movable materials. If there is already a pallet of that material in the picking area the other pallets will go to a reserve location and wait there until the pallet in the picking area is empty. Most of the products are stored as full pallets and also arrive as so from the supplier. Dividing one location (the pallet on the location) with two or more materials is also possible and used.

Picking destination is usually a cardboard or plastic box (or it could be a pallet if there is a large shipment to one customer picked mainly from fast mover). Picking area is divided into sectors and in the middle of those is automatic box conveyer line. The line provides a box of each order, where to pick. When the picking is done, the filled boxes are returned to the conveyer line, which will deliver boxes to next step that usually is the packing and box consolidation station. Some of the boxes are coming from ABW picking stations and are already partially filled with material picked there some are empty when arriving to fast mover picking zone. If all the products won't fit into one box, the order must be split to two or more boxes. That creates some extra work, since the automation does not provide extra pre-build boxes to fast mover warehouse.

On the picking area pallets are lying on the floor allowing employees to do the picking by hand. Movable picking cart is used, which can carry 4 to 6 boxes. The employee also has a tablet-pc connected to warehouse management system to provide orders and a barcode scanner.

The employee loads the picking cart with up to 6 boxes from the conveyer line. Those have unique bar codes, which are already connected to an order. When raised to the picking cart the employee tells the warehouse management system which boxes are on the cart. The WMS creates the picking route and gives the picking orders. It tells every location where to pick and the amounts of each SKU to each box. The employee follows the orders and picks correct amounts to correct boxes. Serial number reading and protection is also done when needed while picking. When everything is picked, the boxes are returned to the conveyer belt and the process starts again.

5.2.3 Manual and Od-size warehouse

Manual warehouse is a basic warehouse for standard size pallets. Its shelves are about 10 meters tall and have 5 to 6 levels. Od-size warehouse can be seen as manual, but it has no selves and pallets are directly at the floor. In manual warehouse two bottom most levels (ground level and first shelf) form the normal picking area and are available for less than a pallet picking. Upper levels are reserve locations to picking area and available for picking only if the whole pallet will be picked. Warehouse is operated with different types of electrical forklifts.

Storing is done with reach trucks, since those are the only ones that can reach the highest shelves. Reach trucks also handle transportations from reserve locations to active picking locations and full pallet picking. Driver of the truck has a pc with a bar code scanner on the truck and a list of transportations they must execute. Items in hurry can be prioritized on the list.

Picking can be done by whole pallet picking, direct parcel picking or group picking. Whole pallets can be picked straight from the shelves. If the pallet is taken straight from shelf and to be send like that, it will be directly moved to outbound with reach truck. That can be done and is usually done from reserve locations. This is called whole pallet picking.

Less than whole pallet picking is done with vertical order picking trucks (rider order picking truck), which are human raisers. With those machines pickers can reach the first shelfs easily and safe. This has been divided to two processes and two different picking methods: direct parcel and group picking. Multiple orders can be picked simultaneously to a pallet, but by system, and for simplification of the work performed, limitations only neither of the methods direct parcel picking or group picking.

Direct parcel picking is only applied if the material can be sent away in the package where it is stored, in other words a product (or multipack) can be sent away like that and no packing is needed. Direct parcel picking requires that products are well packed and protected. Most importantly the package won’t be ruined during the transportation or the customer does not care if there is some scratches or marks. Basically, that means products that are not packed to consumer packages and are mainly packed to brown cardboard boxes. Direct parcel picking is usually done with a rack, which is shipped like that.

Group picking is like ABW and Fast mover picking and the destination is a new cardboard box. Many items (a group of items) can be picked to one box. An order picking truck can carry only 4 to 6 boxes depending the size used. When the picking is done, the parcels are left to conveyor belt at the side of the warehousing area and the line will transport parcels to packing stations.

Both direct parcel and group picking are done by vertical order trucks which are equipped with tabled, bar scanner and printer for shipment labels. Warehouse management system defines the optimum picking routes and employees follow those orders.

5.3 Packing and Consolidation

Packing and box closing is done at a specific packing stations. Automation transports the parcels from picking areas to the packing station. All new cardboard boxes, which are filled with products at group, fast mover and ABW picking, are going true the packing station. Small orders are picked to temporary plastic boxes. Those items are moved from plastic box to small sized cardboard boxes at the packing station. One packing station have one incoming line and one outcoming line. Both lines end at a table were the box closing and consolidation is done. The station has a PC with WMS running on it and needed material nearby, including new boxes and a supply of sealed air.

Employee receive a box from conveyor line and simultaneously see the content at warehouse management system on screen placed beside the station. If the box is a temporary plastic one, employee takes a new small prebuild cardboard box from a self behind the station and puts the items to it. Employee inspects that information and products are matching, products are in good order in the box to be transported and fill the empty space with sealed air. If something is out from order it is rearraigned. Packing list and other needed documentary are put in. Boxes are closed and sealed with a tape. After that the employee will acknowledge the parcel to be ready to the warehouse management system and send it away with next conveyor belt towards the outbound area. The empty plastic box is also send away.

5.4 Outbound

The outbound is the place were parcels and pallets are sorted and sent away. Single parcels from fast mover, AWB and group picking come from packing stations via conveyor line. Already sorted and filled racks and full pallets come from manual and od-size warehouses. Parcels are mainly sent in steel racks or on normal wooden pallets if pallet consolidation is done. Pallets go to customer's locations as whole. Parcels on racks are transported to transportation company's logistic centers and resorted individually to customers all over Finland.

If shipment to one customer location is formed with multiple parcels and weighs over a certain economical limit it will be shipped on a pallet. The parcels are transported to outbound and pallet consolidation is made in the outbound. A parcel that will be consolidated arrives like all other parcels to an outbound line, but is packet to a pallet instead of a rack. Usually some lines are assigned to consolidation.

At the outbound parcel coming from packing station are sorted up to 10 lines. Lines have different shipment locations or shipping methods. The line layout can be changed during working hours to match the current need. Racks to different locations are placed near the line supporting it to make it easy to find the correct rack. Employee's responsibility is to check where the parcel is going and put it to right rack or pallet. Different transportation companies and different styles to customers with high volumes can be arranged to specific locations.

Pallets are checked to contain all ordered material and are frapped with a wrapping machine to secure the material during the transportation. Packing list and shipping documents are attached to pallets if needed.

The transportation activity was not a part of this study, but it is related to the outbound and affecting its work. The Company X has outsourced its transportations to specific transportation companies. Company X has a team of employees responsible to organize all the freights from company X to customers. Also returns from customers and from Company X to Suppliers have been organized by the transport team. Salaries and general cost created by the transportation team are not included in this study. Neither the freight cost was a part of the study, since Company X already has system to allocate those.

Different transportation companies are used with different customers and different shipments. Basically, that creates no difference to outbound activities, since packing the parcels or preparing the pallets and picking up is the same regardless of the transportation company. Goods are loaded to the truck by the truck driver and shipping documents are handed over to the driver if needed. Most customers are domestic, but there is a small number of oversea customers. Shipments to other countries create extra work for the transportation team and a little to the outbound as well. That is caused mainly by customs and different needs on the other countries. A bit more documentation is needed and usually pallets are wrapped with non- see through wrap to prevent thievery at long haul shipments.

5.5 Process conclusion

The process overview was performed to have process information to the cost allocation system and a bottom line for process improvement. The second research object, to create process knowledge to value the needs and alternatives of process improvements, is filled only after next chapter, where performance measurements are left to. Assumptions based on process mapping are now created and listed below. Those were used as a bottom line to measure the performance.

In this chapter the actual processes at Company X were modelled. Only one new improvements were considered. The effect of the improvement should be clear and the implementation date was close. One technical improvement to was applied before it was in use, otherwise the actual processes as those are performed were modelled.

Main modelling tool was textual instruction which was backed with flow charts and diagrams while needed. This was found out to be efficient level to clearly explain the 5 items to needed to define processes. Processes were identified and their hierarchy and interaction with customers internal or external where stated. Mission and responsibilities where explained.

Overall, the warehouse type, where the product is stored, is the main factor to effect on the processes' performance and further on to the cost assignment. Different processes were evaluated by the process modelling and similar processes were compared to each other. Basically that meant comparing different warehouse areas and inbound and outbound processes related to those. These assumptions were done by the thesis worker, and the logistic manager from company X confirmed that those are reasonable. This will create a base of assumed cost and will be seen if this will be confirmed with time driven based cost calculations in the next chapter.

First the assumption was that automated box warehouse area is cheaper than the others by transactions, but high investment cost and high density of transactions is of course raising the overall cost. Other down side is the small storage space per location, which makes it time consuming if a product is stored to multiple boxes. So, other assumption is that it is not very effective if SKU is really movable or large by physical volume. This was why the fast mover warehouse was created in the first place.

Fast mover warehouse is also assumed to be cheap by outbound end transactions. Warehousing is assumed to be really costly by warehouse location. Meaning that especially if there is only a small quantity of items per pallet, and if one SKU stays there for a while, this warehouse area is expensive. Inbound transactions are also assumed to be time consuming and costly, but if calculating per SKU the high quantity of products on a stored pallet will lower the cost a lot.

At manual warehouse the volumes and strength of transaction lines is assumed to be the key to lower cost. Manual warehouse is assumed to be the cheapest by warehousing costs by normal physical volume warehoused. This holds an assumption that multiple items are stored to one location. Both inbound and outbound transactions are assumed to be more time consuming than ABW or FM if calculating single transactions. On the other hand, if calculating a single SKU in one pallet the inbound or picking cost could be significantly lower, especially if full pallet picking is used. Picking light picking lines is assumed to be costly. Od size is assumed to be similar by transactions with manual, of course mainly full pallet picking is used. But by the means of warehousing cost the od size warehouse is assumed to be tremendously more expensive than manual.

6. COST CALCULATIONS

Time driven activity based costing was decided to use as a base of the cost calculations by the project sponsor in the beginning. Whether that was a good choice will be seen within the study. On the other hand, the cost calculations were simplified and especially the day to day cost allocations were made a bit simpler by using time driven ABC and applying it. When more work is done at the cost calculation crafting project, the day to day operations can be performed more easily.

The implementation of the system must be possible within the accessible resources. System must be easy to use and updatable. Too complex system is invalid as seen in literature review. On the other hand, the matching principle must be satisfied and valid data must be accessible, if not the cost allocation system is invalid and the information it provides is worth nothing and can ~~be~~ even lead to bad business decisions.

The distribution center can be seen as one department in the company, which consists of multiple of processes. As was written in sub chapter 3.5 citing from the book by Kaplan & Andersons (2007), distribution center does not have homogenous enough process base to be used as one solid costing unit. Process view is creating more complexity, but it is appropriate to use, since the distribution center is organization's core business and its performance is crucial. Also, this thesis aims for deep understanding of the cost created in the distribution center. If the distribution center was just a part of a manufacturing facility, a simpler view could have been used. Process view is taken into account by combining different resource pools as Demeere (et al. 2009) has done with their study. Those cost pools are combined to cost centers with specific capacity cost rates.

6.1 Cost centers, Narrowing the process indicators for cost calculations

In the Company X distribution center is divided into many logical processes that can be seen and were described in the previous chapter. Based on that, the costing centers have been created to be able to craft the estimations of the process times and capacity cost rates. During the project, three different kind of models, of how to use cost centers, were found. In the end one was chosen for further research. Easy to use, possibility to implement with given resources and enough precision where the evaluation criteria. Sponsors from the company X with thesis worker chosen the cost center model which was refined to be used with cost management. Actually, this was more of an iterative and evolutionary process than simultaneously comparing of three different models.

Basically all this narrowing is done to aid the usage, updateability and implementation of the costing system and decrease complexity with IT and data taken in and out form cost allocation function. Precision with cost allocation has been tried to model with less work and with more homogenous system. To get there, simple modifications to cost calculations compared to pure TDABC model (created) by Kaplan and Anderson was made.

6.1.1 Widest with all processes individually as cost centers

The first assumption was to use all the identified processes listed below as their own costing units and to create all time equations and capacity cost rates to all of these processes.

1. Inbound
2. Storing
    2.1. Automated box
    2.2. Full pallet
3. Warehouse areas (warehousing):
    3.1. Automated box warehouse
    3.2. Fast mover
    3.3. Manual
    3.4. Od-size
4. Inner transportations
5. Picking
    5.1. Automated box picking
    5.2. Fast mover picking
    5.3. Picking from manual warehouse
6. Box closing & consolidation
7. Outbound & pallet consolidation
8. Transport

In total that takes 14 processes that should have been calculated (if there is an upper level process containing sub processes, only the sub processes are counted in). Some of the processes have a lot similarity. That can be also seen from the names and was written in the previous chapter. Still all sub processes in different areas differ in action and more importantly the capacity cost rates are based on varied factors. First 13 are directly handled in the warehouse by Company X. The Last one is a bit difference, since that is mainly done by external transportation companies.

All in all, using 14 individual cost centers, turned out? to be too complex and would have over run the resources that were assigned to this project and more over the using and maintenance of the cost calculations would have been too demanding compared to the current resources. A Too complex model leads to second option that was given as successions by a controller from Company X.

6.1.2 Very simple with only 3 cost centers

The second option was the narrowest one. The processes are divided only to three categories: Inbound, warehousing and sending processes. Those three will be the cost centers and measures are made based on barely those.

This was found to be unsatisfying and was denied. Differences between processes were turned out to be to be too great. For example, Automated box picking and manual warehouse picking uses quite different resources. The accuracy of the calculations and honoring matching principle seemed to be at risk.

6.1.3 A Compromise

Neither of the previous models were found to be satisfying. The final form, which was selected to use at the end, was a compromise between the first two. Like in the second option, only three real actual cost centers are being used. Besides that, a background system was created to match the complexity and to honor the matching principle. All the processes from the first option, expect the transport, were cost modeled and calculated to the background system. These formed artificial cost centers within the three actual cost centers. All transaction within those three cost centers were valued and tracked to a database.

The complexity between and within processes are modelled with fixed cost rates from every process. Time driven activity based costing is used to craft those fixed cost rates from certain transactions. When a transaction is performed, a stamp is created to the database to resemble it. The fixed cost rate will tell how valuable or costly that one stamp is compared to other stamps from the same and from different processes. When the stamps are created the actual cost driver will vary depending on the dimensions of the transaction. Four different stamps are created.

1. Inbound
2. Warehousing
3. Picking
4. Sending

For an item, going true the whole process within Company X, stamps 1, 3 and 4 are occur only once, but the warehousing stamp will continue occurring every night while the item (alone or with other items) is occupying a warehouse location.

This model leads to the use of the tree actual cost centers, which were used by the controllers, and information from the cost management system was forced to be based on those. Artificial cost centers were used behind those real ones, to catch the complexity. Artificial cost centers were based on processes listed on the first model, with small modifications. Inhouse transportation, full pallet picking and full pallet storing are used as one cost center. Direct parcel picking and group piking are really close to each other from the cost management view.

Capacity cost rates are crafted to all cost centers individually, but also Demeere's (2009) view of combining different cost pools is used as an advantage, since many cost centers use the same or similar resources. After that, the process times and time equations are verified to each process.

Although the cost calculations are based on TD ABC, the actual model is more of a simplified modification of it. All the transactions will have a certain fixed intensity compared to other transactions in the same real cost center. The intensity levels are calculated with time equations and the cost of time is verified to each process individually.

Time equations and capacity cost rates are used with the artificial cost centers. The model takes the cost calculations closer to the traditional activity based costing or even job order costing. Of course, TD-ABC and ABC with time as a driver are by definition quite close to each other. On the other hand, the aim of this study is not to use time driven activity based costing or regular activity based costing as pure model, but to create a reasonable and accurate enough model to face the challenges in the Company X.

The assignment of transportation cost is not discussed further on this study. The driver at it is weight. It was done simultaneously with the project, but not within it.

6.2 Capacity cost rates

Capacity cost rates were identified to all artificial cost centers. Some of them share the same or similar cost pools. In this thesis and in the project behind it with Company X, we focused only on the cost created by the logistics activities (mainly warehouse). All other costs were left out of this examination. For example, functions as purchasing, product management and sales & marketing are not involved in the examination, even though those are directly in touch with the products. Overhead made by the management of the company are also not involved. Challenge is to allocate all those included costs to the right cost center and further on to costing units with time equations in the next sub chapter.

Since logistical processes do not make any actual changes to the products, resources like raw material do not basically exist. Processes are directly using resources like workforce, machinery, and packing material.

Capacity cost rates were crafted only by using the main resources consumed by the cost center while performing activities. In other words, only noticeable costs were counted in when creating the capacity cost rates to each cost center. The key was not to allocate all the actual costs by penny, but to be able to value and compare the transactions on one artificial cost center. This is supporting the model, where all costs from actual cost centers are divided between intensity rates and transactions performs. The allocation of some resources was manipulated manually compered the actual usage of the resource, this was a decision made by the project team. Greatest example of that is the occupancy cost, which is allocated only over the warehouse areas.

General costs, like IT hardware and software (including warehouse management system) and warehouse management, where not allocated at all to any artificial cost center(s). Those resources were seen to be used evenly by each and every transaction in the warehouse. That's why every transaction should get an equal share of it and it would be easier to assign directly than via cost centers.

6.2.1 Main resources

Main resources used by the distribution center's logistic activities are:

- Labor
- Occupancy
- Machinery (automation system, moving machinery and selves)
- IT
- Packing material

Labor can be divided to floor workforce and management. Management (were) seemed to be divided evenly between the cost centers and activities compared to performed work like IT. Floor workforce was of course seen to be directly in touch with the activities and the performance. It is one of the major resources and had a large impact over costs.

The capacity cost rate of employee usage was computed from annual averages of the costs of floor working employees, which were available from accounting. Controller from Company X, thesis worker, and logistic manager concluded that it was the most accurate and valid number to use. This cost included the salary and all other employee related cost listed in chapter 3, such as benefits and health care costs. To match the actual capacity offered by one employee, this annual rate was divided by 11 months, 21.5 workdays per month and 7.5 hours per one workday to create an hourly cost rate, which could be divided by 60 to have cost rate per minute and likewise further on to seconds.

Occupancy resource contains all space and building related costs. Costs directly related to managing the building itself and heating, electricity, water etc. Electricity and mainly heating cost were assumed by the specs of the building and machinery. Difference between winter and summer time is not considered and the assumed annual heating costs are divided evenly to months.

Machinery resource includes the warehouse automation system, all moving (and stationary machinery), and shelves at manual warehouse. Automation system and shelves were investments and the bookkeeping depreciation value was used. With the automation sys-tem the resource cost was divided to the processes using it. The driver for it is the per-centage share of the values of the components which are used in those processes. The split is on table 7.

Table 7. *Automation system split*

ABW storing stations	9,8 %
ABW picking	36,2 %
ABW warehouse	37,9 %
Group picking	1,7 %
Fast mover picking	14,5 %

Over the investment cost the general maintenance fee was assumed. Maintenance is a combination of planned services and needed repairing that are hard to predict. Normal repairing and maintenance is done by Company X's resources. Additionally service parts, purchased services, and extra work force is needed from time to time to manage greater services or repairs. This estimation was done in a very non-scientific way by the three-person team mentioned before. It was done by applying the speck of the system, promises and information given by the system provider and knowledge gathered from use of this and previous machinery. This was seen as given number and the accuracy and validation was not questioned.

Moving machinery is leased and it had monthly payment by the machine, which was easy to use as resource cost. If some of the machines were not leased, the cost obtaining it was calculated to match the leasing cost. Machines are divided to different processes. The utilization level is varying quite a lot between different machine types. This was considered if possible. Utilization levels were calculated to each machine to create more accurate minute costs. Machinery and their cost, main user(s) is listed in the table 8.

Table 8. *Costs and user of moving machinery.*

Type of a machine	**Cost per month per machine**	**Main user(s)**	**Usage per month (May and June 2016)**
Pallet trucks	X26	Inbound 50% Outbound 25% General 25 %	Unmeasurable
Small pallet trucks	X19	ABW storing	X23 h
Stacker	X73	General	Unmeasurable
Reach trucks	X74	Transfers 80% Whole pallet p. 20%	X77 h
Picking truck	X46	Group picking 52% Direct parcel p. 48%	X30 h
Counter balance	X43	Inbound General	Unmeasurable

Small pallet, reach and picking trucks are used only at the specific processes, and potential working hours are strictly connected to them. The minute cost of those machines is computed with the actual usage hours per month. Pallet trucks, stackers, and counterbalance trucks are used in general purposes and their usage is not possible to assign directly to those processes. The minute cost of them is computed so that each machine is used 8 hours per work day, which is basically 50% of the possible capacity. Stacker is not used in any core processes. These timely costs are used with process focused cost centers in-creasing the cost if the machine is used.

6.2.2 Inbound operations and storing

This area contains the processes, which are included in the first actual cost center. At the inbound area the main costs are employees and moving machinery. This was divided to two artificial cost centers and two capacity cost rates were created. One is over the inbound activities and full pallet storing and other is containing the ABW storing process.

On inbound process the capacity cost rate was calculated per one employee, who is using one pallet truck and a half of the calculated capacity of a counterbalance forklift. This created a capacity cost rate 0,X03 euros per minute.

On ABW storing process also one employee is the bottom line of the cost rate. A share of the automation system is included and one small pallet forklift per employee. The automation system share to this process is divided by the assumed working hours on all storing stations combined. The capacity cost rate over this process is 0,X14 euros per minute.

Inner transportations is strongly attached to this cost center, even though it is seen as a shared resource. Most of the inner transportations occur when pallets are stored to warehouse locations or moved from reserve to active locations. Inner transportation's cost rate is a combination of one employee and one reach truck. The capacity cost rate over this process is 0,X53 euros per minute.

6.2.3 Picking and outbound operations

All five picking methods have different capacity cost rates and packing station and outbound area have their own. These are measured by the employee utilizations which creates the capacity to perform the activities. All picking methods have quite similar calculations utilizing an employee and machinery. While crafting the capacity cost rates, the share of automation costs created by packing station and outbound are included to picking processes. This is divided to different picking methods by the share of the picked lines.

AWB and fast mover picking both utilize an employee and a share of automation system. The minute cost of the automation is calculated by dividing the monthly cost to minutes used by the utilization in a average month. The share of total cost of automation assigned to these processes can be seen in the table 7. The utilization level of picking stations by hours is: AWB 950 and FM 370. The capacity cost rates are 0,X82 euros per minute with AWB picking and 0,X85 euros per minute with fast mover picking.

Group and direct parcel picking are similar on the capacity cost rate view, expect parcel from group picking are going true packing station while direct parcels are going straight to outbound. This makes the difference to the capacity cost rates, which are 0,X54 euro per minute with group picking and 0,X17 euros per minute with direct parcel picking. With full pallet picking same capacity cost rate is used as with inner transportations.

At packing station only employee cost is counted in. Outbound have been seen quite similar compared to the inbound, except the share of the counterbalance forklift is smaller, only a half of what it is with inbound. The capacity cost rate is calculated per one employee who is using one pallet truck and a half of the calculated capacity of a counterbalance forklift.

6.2.4 Warehousing

The nature of warehousing process is different than all others, which are more action based ones. Both capacity cost rate and time consumption per transaction are different with the warehousing. The costs are assigned to the costing units via utilization of the warehousing locations. If a warehouse location is occupied by a SKU (or many SKUs) at the end of a working day, it is taken into account and the cost of the location per day is assigned to that SKU(s). Because of the daily costing, the warehousing process is not discussed further in the next sub chapter, since all the time consumption is always one day at time and no time calculations nor time equations.

This is the part of the process when SKUs are lying on the shelf. All the warehouse areas form separate cost pools, but costs allocated to those are mainly the same. Most significant costs are occupancy costs. With the automated box warehouse the cost of the machinery is a significant factor, as well at the manual warehouse the shelves were a notable cost.

All the warehouse areas have separated cost pools. One warehouse location has a certain fixed cost ratio per one day, which is carried on after every work day. One location can hold one pallet or AWB-box and the cost is divided to the SKUs in the pallet or box. Basically the cost per one item is increasing when some of the original amount have been picked away.

The capacity cost rate of warehousing is calculated by the cost assigned to that area and divided by the number of storage locations of that warehouse area. An average of 21.5 working days per month was used to define the daily cost. At First, standard cost rates were crafted with 100% utilization, but afterwards the cost can be divided only to occupied locations or still to all. In that case, all of the costs are not assigned to any product, supplier, or customer. Those methods give different results and both can be seen beneficial to the subject organization, regarding where the cost information is used.

All of the occupancy costs were assigned to warehousing. This was a decision made within the project by the project team and it is not scientifically proven to be a correct or valid. The reason behind the decision is that the main reason to have this whole facility, is to keep products at stock and ready to be picked and sent to customers. Total cost assign to warehousing was firstly divided to warehouse types by the share of the square meters which the warehouse type is using compared to other warehouse areas. Other significant costs were the deception and maintaining of AWB warehouse and manual warehouse shelves, which is significantly smaller as a total sum. With these costs the calculations were kept simple. The difference on daily cost of one location in each warehouse type can be seen in table 9.

Table 9. *Daily costs factors of the warehouse areas*

Warehouse type	Cost per working day
AWB	1,0
Manual	9,4
Fast mover	87
Od size	61

As can be seen, the daily costs have large variation between different warehouse areas. Of course the storage volume in one location is larger with manual, fast mover, and od size compared to AWB.

Time spent in the warehouse has been valued on nightly basis, while on other areas time was measured on seconds or minutes. If the location is occupied when a working day is over, the cost of it will occur to the SKU(s) on it. If two different SKUs are occupying one location, the cost is divided by two and with three different SKUs by three and so on.

All the occupied locations in one warehouse area will have the same cost per day, regardless of the actual volume or weight that the items use in it. From cost assignment point of view, a location is always fully occupied or empty. When a location is occupied, even with one small item, there is no possibility to store another pallet or box to it, which can be seen as the main reason to give the full cost to all occupied locations. In most cases one location has only one kind of items on it. In that way, the cost driver is inspiring to maintaining the warehouse locations as productive as possible. For example, if items of the same SKU are stored in multiple locations. It is more beneficial to fully pick the first location and then start to pick at the second one. In that way, the first locations are faster ready to be used again, with new items.

If there are multiple SKUs in a location, the split is even regardless the actual volume used, the quantity of item, or weight SKU's have. Using the actual volume, quantity, or weight as a driver to split the cost of one location, seemed to be difficult to use. It would make the calculations more consuming, but the value gained from it was not clear, or not verified at all. If even one piece of that SKU is occupying the location, the share of nightly cost will be assigned to that SKU. This seemed to be a fair way~~,~~ to split the cost of locations where multiple items are stored. Locations with multiple SKUs are usually not full by weight or volume. This creates a possibility to add other SKUs to the location, but totally new pallet could not be stored to the locations.

6.3 Estimating the process times and time equations

Time equations where formed based on process definitions and where specified to a cost centers illustrated in previous chapter. Actual time consumption analyses where crafted and verified by multiple methods. First the assumptions of the time consumption were created by the thesis worker (and verified by logistic manager), which were verified with observation on actual time usage, interviews with employees and management and/or using ERP data and performance management reports. Since the facility was still a bit shattered and in ramp up stage after a momentous change, all the processes are not performed in 100% efficiency, some of the time drivers where adjusted to meet the confirmed near future process improvements.

On inbound and outbound end similar and real time consumption with time equations was used. Warehousing is a different one, since it is measured by days when the items are kept in stock. Whole stock is measured on daily or more precisely on nightly bases.

Inbound and picking are based on transactions. On the inbound end from all a way form unloading a truck to finishing the storing only one transaction stamp is created. On the outbound end two stamps are made. One is from the picking process and other one is containing box filling & closing and the outbound processes. One stamp should include all the sub processes faced by one unit going from the truck to warehouse self. Since that a sort of time equations was formed, but also the capacity cost rates are different between the process.

6.3.1 Inbound and Storing

As mentioned before this sub process contains all the activities from receiving the products from external truck transportation to storing them to warehouse locations. This pace contains four sub processes, but basically the cost management calculations made a split to two: ABW-storing and full pallet storing. Same capacity cost rate is used with inbound area activities and full pallet storing. ABW storing have one which includes the automatic transportation to the ABW shelf. The fourth process and third capacity cost rate is the inner transport, which transports the full pallets to storage location in manual, fast mover and od size areas.

Inbound is a troublesome process to model accurately. Variety how incoming shipments must be deal with is great, and there is no specific data over it. This is mainly a problem with pallet storing, but also with the plastic boxes. Although the overall felt variety is significantly lower with plastic box storing than with pallets.

Basically storing is the first accurate transaction from the incoming products, which is stored to any data pool. All received lines are documented to the warehouse management system by the shipping documents and received lines are stored by using that data. But it was found out to be impossible to get any knowledge from the shipping documents, which would help to model the performance and time consumption on SKU, shipment or supplier level. There was no useful information provided by the shipping documents that could actually be used to model the variety of complexity on the inbound and storing process and further on to assign the extra cost created by the complexity to specific SKU, shipment or supplier. The Shipping document do not show the actual structure of the shipment and how the pallet are needed to be handled.

The time consumption at the inbound process was tried to model by discussions with employees and management and with observation over the work performed at inbound. Manual performance measurements and tracking of the flow of individual products were tracked. Basically two morning shifts (when inbound is more busy) were observed. The time consumption of all tasks done by one employees were timed. If other employees were working on the area that was noted. Working at the inbound basically consist of four activities: transporting pallets form a truck to inside and labelling those pallets, handling the shipping documents, sampling the products to ABW-storing queue and others to storing platforms and storing full pallets to warehouse management system.

Transporting pallets form a truck’s platform to inside is quite stable if those incoming pallets form supplier are counted. 150 incoming pallets were timed and the average time consumption was 1minute 27 seconds. This time consumption also covers the labelling, which creates the connection between the pallet and the shipment and further on to purchase order and items on it to the warehouse management system. This plain number of time consumption cannot be directly used since all of those pallets are not directly stored, which actually leads to the biggest problem in the whole project. How to model the process where incoming goods are made to be ready to be stored

The pallet sampling was observed and measured with quite same mass which has just been pulled in. Usually one shipment is sampled to new pallets at once. All products stored to new pallets are sampled and small items are taken to the ABW storing queue. It was hard even to measure the exact time consumption per one new pallet which will be stored, since multiple pallets and items are taken care of simultaneously. One mixed pallet is handle by time and it gives two or more pallets, which will be stored and may give items to ABW storing queue.

While observing a great variation between pallets was noticed, which was expected based on the process modelling. The biggest difference was between direct pallets and sampled pallets, but also notable difference between repalleted and direct pallets were found. While direct pallets basically have no time consumption in this part of the process, the repalleted have about one minute extra and the totally new pallets take 1 to 10 minutes extra. Above five minutes were quite rare and usually those contained some problems or interruptions. Splitted pallet are a special case between direct and sampled pallet. Time consumption is also somewhere between. Time effect of each type is collected to table 10.

Table 10. *Time effect and share of each type of full pallets sampled*

Type	Time effect	Approximated share
Direct pallet	none	7,5 %
Repalleted	1 minute	5 %
Splitted	1 to 4 minute	2,5 %
Sampled	1 to 10 minutes	85 %

The share of each type of pallets was also hard to define with limited observation time. Supplier and product group was found out to be affecting to this, but the accuracy was poor. There was found out to be a lot of cases where there was no repetitiveness. At first time same SKU was in full pallets and next time it was in mixed pallets and have to be sampled. This was observed while observing the inbound process in general and the pallets storing queue was analyzed multiple times afterwards. It was easy to make assumption, what have been done with each pallet. Nevertheless, only some product groups were found out to be most likely in full pallets or on small pallets and only needed the repalletation.

This lead to conclusion that there is no straightforward way to model the actual time consumption accurately. Neither the available data nor observation lead to any conclusion how the cost should be allocated between products nor any good findings how to focus future research on the matter. All the observation lead to quite speculate results, which can be changed from one week to other. Only note was those some product groups which usually were in whole pallets or on small pallets. This all led to a conclusion that only averages between each stored line was used to assign the inbound area costs. Basically all the stored full pallets will have exactly the same time consumption number. Other ways might not lead to better solutions and might be too hard to craft or use.

Overall, an average of two and half minutes was chosen to be a valid number of time consumed to all stored pallets from this part. This average is taken account the portion of the pallets that are direct, split or sampled. This will unfavorable direct pallets and favorable sampled ones. For further development to the system, this part was leaved open and ready for changes.

The project team's and mostly the implementation team's timetable and resources were against deeper data analyses over inbound actions. Taking only the intermediate was found out to be satisfying to get the system overall started. Afterwards this could be verified more. There are two options:

1. Automatic tracking of sampled and direct pallets (including repalleted). Deeper comparing and analyzing between incoming pallets and stored pallets via help of data or information system.
2. Giving suppliers and product groups factors, which will be affecting the cost stamps at inbound activity. Those could be based on further observation.

While there was not good enough information available to the first option the second option was tried to execute while trying to do time equations, but at the end it was left away at least for now. Key was to find some logic how to predict the variation with possible attributes provided by the measured data. etc. product group, supplier or dimensions of the product. Pure product level was noted to be too resource demanding. Yearly there is thousands of new products and even total new product categories. All this would have needed more complex calculations and frequently performed updates on the factors.

The time consumption of the transportation from the inbound area to warehouse location was verified by observation and transportation actions were timed. With this observation, no significant differences were found between storing to different storage locations. Of course, it was a bit faster to transport closer and not to the highest shelf. On the other hand if the a pallet was placed to picking area (the lowest selves, fast mover area or od-size), the transportaion usually took longer. There was usually something on the way for example an empty pallet or packing material form the old pallet. This was the main reason why inner transportations from reserve to picking locations were slower than first inner transportations.

The differences between different storage locations were left out and all the transportations from inbound to warehouse locations are treated equally. This was because: observed difference was small between distinct locations and because it is not reasonable and fair. Assigning this differently to business dimensions was seem to be unfair and there is no reasonable reason to do it. The customer, supplier or even business manager inside the Company X cannot actually affect where those items are stored.

The average measure time for the first transport was about 3 and a half minutes and if a second transport is needed it was about 4 minutes. The process was quite new while the measuring was performed. Employees seemed to be more used to take pallets from the inbound rather than reserve locations, which are elevated levels at the selves.

AWB storing’s time consumption was firstly assumed with discussions and overview to the process. Secondly it was more refined with observation and backed up by data simulations with wider data. Two different sup processes were found out to have significant impact over time consumption: the actual storing and getting a new pallet form storing queue including the disposing of the old empty pallet.

On actual storing overview on process and discussions with employees and management success that quantity of the products stored to one box is affecting the time consumption per one box. By discussions product group, weight or other specific attributes were not felt to affect as much as the quantity. This was the base assumption with measurements.

202 storing transactions were manually timed. Product number, quantity, platform number and spend time were documented. The accumulated time was measured from starting of storing to point when the box was pushed to the automatic conveyer belt, which was also the starting point of the next storing transaction timing. If something else was done, that was also measured but left out from this analyze. Time consumption as quantity’s function is plotted in figure 9.

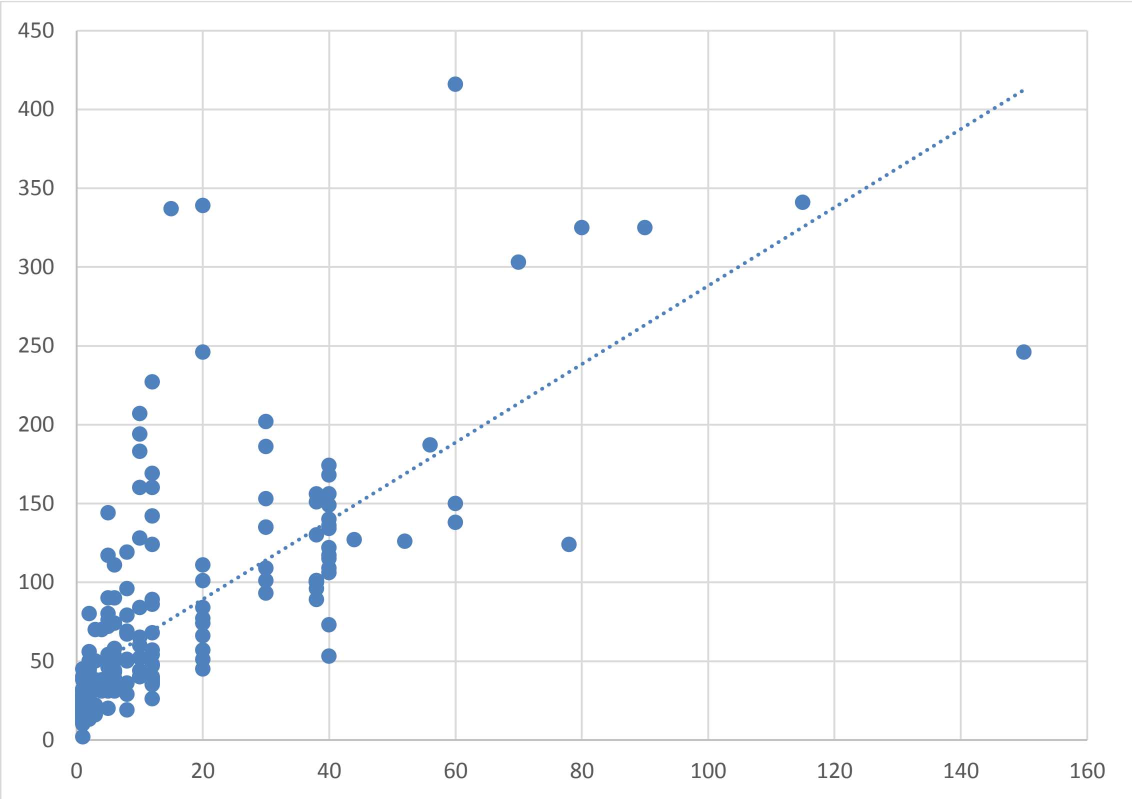


Figure 9. *Plotted time consumption to unit quantity*

On the time figure 9, it is clearly visible that most of the storing lines have smaller quantity than 20 and quantity over 40 is rare. This was confirmed to be true with larger ABW storing data. Quantities over 40 are rare and over 100 are extremely rare. Less than one percent of the transaction have quantity over 100 and over 90 percent have less than 40 pieces. On blame eye a correlation, not a strong one, is visible, with a linear trend line it is even more visible. This is supporting the first assumption.

Stored quantities are seeming to be accumulated to certain numbers like 1, 4, 10, 20 and 40. This is because items are often ordered on even or equal tens and bigger multipacks often have even number, equal tens or some other standard number.

Some workers first arrange a load of multiple boxes to the table and afterwards store them all quite quickly. This is even more common if same or similar products are stored to multiple boxes from one pallet. This creates the biggest variation and most of the timings notably above the trend line are because more time is used while arraigning the load of multiple boxes'. On the other hand, the rest of those have smaller time consumption, which also can be seen from the figure.

The quantity of stored items was found out to have an effect on the time consumption on this process and it should be taken account with the cost assignment. A function to model that was needed to model the differences between different quantities to the time equations with this process. A linear trend line was chosen to be the model. It was found out to be more accurate and usable than logarithmical functions or functions with greater or smaller degree variables. It is also the easiest to use.

The time consumption of the disposing an empty pallet and getting a full one was also measured while timing the storing process. It was found out to be a little less than six minutes per pallet and was rounded up to exactly six minutes. This included all between the end of last storing and the beginning of the first with a new pallet. Most workers do a small clean up to the station before starting to work with a new pallet. This time consumption is needed to be shared between all the storing transactions form that pallet. The number of stored boxes from one pallet was measured while measuring the time consumption, but also with assuming the potential number of the boxes from the pallets at the storing queue. This was done three times. The assumption of average is 35 and the result of measurements was 9 to 49 boxes per one pallet, which was supporting the assumption. 35 stored boxes per one pallet was chosen to be used.

The linear function directly modelling the trend line in figure 9., would model the time consumption of the actual storing. The function was rounded to be 2,5 times the quantity plus 37, the result is in seconds. The problem with linear function (in other words a straight line) is, that it is continuously increasing with same pace. This was fixed by setting a limit to 100 pieces and all values over that will return the time value of 100 pieces. With logarithmical function that would have been under control, but the values from quantities below ten especially with one and two was found out to be unsatisfying. The logarithmical function was growing too fast on low values.

The value from the function was used as an base and 14 seconds for pallet change was added and this combination presents the ABW storing process. This result was found out to be satisfying, while comparing time consumption calculations form daily transactions to daily working hours.

Cost from the inbound area needs to be added to all products stored to the ABW, since the cost stamp is presenting all the cost form receiving the delivery to storing to the warehouse. Pallets are handled at the inbound before those are taken to the ABW storing queue. Those are using the three phases of the inbound process presented in figure 8 at the previous chapter. The cost effect of those is calculated by used inbound capacity per pallet and dividing it to stored boxes similar as pallet chancing. Time consumption per one pallet was evaluated to 5,25 minutes. Which was also divided to 35 stored boxes per pallet. The inbound capacity cost rate was used with this time equation and two cost values were sum up to make the total cost of inbound for SKU’s stored to ABW.

In total the inbound operations have two different cost to assign to the incoming products. All the AWB stored items will have the cost ration per one box based on the equation and all pallets will have fixed cost per pallet.

6.3.2 Picking, packing and outbound area

Outbound is more stable than inbound and easier process to model. Variation between different transactions at same process seems to be smaller than at the inbound. Variation in the picking tasks between products and orders are has assumed to be small. At the outbound end processes the effect from other subsidiaries is significantly lower than in the inbound end. The data from the picking activities and outcoming shipments is much more accurate than with incoming.

Outbound processes were divided in two phases while creating the time equations:

1. Picking
2. Box closing & consolidation and sending (outbound area)

Both phases created stamps to data base and cost can be assign with those.

Further on the picking process was divided to five different process by all five picking methods. The Packing and sending phase was also divided to five different processes by the picking method, but actually only three different processes were found, since parcels coming from ABW-, Fast mover and group picking are going true exactly the same box closing & consolidation and outbound area process. All the picking methods have their own capacity cost rates and packing station and outbound areas have theirs.

Based on process overview a formula for time equations was formed. The base of the time equations is one picking line, which contains certain quantity of one product number (SKU) and is picked from one location to one shipping unit (pallet, cardboard box or plastic box). All picking lines have to be assigned with individual factor based time equations. At picking four different patterns in time equations formula were found out to exist. A base rate to all picking lines was verified to exist, and the strength of the line was noted to have an effect over picking performance. If identifications or protection was needed, those were natural reasons for extra time consumption. If identifications are needed, those are needed form each item on the picking line, so the added time is varying by the strength of the line. Protection was seeming to take quite similar time regardless the strength of the line. This was found out to be valid to all picking methods. That's unlike Varila (et al 2008) suggested in their research, but their function did not consider identification checking or protection which were defined but not taken account while valuing the driver. Also the picking process they were measuring was defined more complex than Company X is currently using. The time equation formula to all picking activities is presented at table 11.

Table 11. *Time equation formula for all picking processes*

Picking line	Base time for each picking line
	+ Time extra* Unit quantity on line
	+ if Identification numbers are read Time extra * Number of identifications
	+ if units have to be protected Time extra

Picking processes were verified with observation (including visual observation and discussions with employees) and with warehouse performance measurements and picking data. Picking data provided all the picking lines and their needed basic information. From performance report the working hours by each picking methods were available. The overall time consumption and picking line specifications were available with those data sources. Observation and discussion was used to measure how different task are compared to each other.

Measuring the picking was found out to be hard to perform, since the overall performance is on hi-level and all the task are performed rapidly. On the other hand the picking tasks are seen more standard and similar among the employees and by observation findings. Task are performed simultaneously and are fast to perform especially at ABW and FM-picking. Trying to keep accurate measuring table from picking was found out to be impossible if all sub tasks were measured individually. Identification reading and At different picking methods the attributes to time equations were crafted with discussions with employees performing those activities. Discussions with multiple employees and general observation over the processes lead to time equations in table 12.

Table 12. *Time equation formula for picking processes*

	ABW	**Fast mover**	**Direct Parcel**	**Group Picking**	**Whole pallet**
Base	25	30	120	150	210
Quantity	2*PC	1*PC	15*PC	8*PC	
Identifications	8*PC	8*PC	8*PC	8*PC	8*PC
Protection	40	40		40	

On the table the 12 the time equations of all picking methods are combined to together. Each column presents one method and each line is presenting one attribute to each time equation formula. Time is measured in seconds and if there is *PC the time value is multiplied by the item quantity on the picking line. One exception was made to time equations formula. At whole pallet picking the quantity on a line was left without an effect of made by the item quantity. Protection is never needed while picking direct parcels or whole pallets at the picking stage. As on example time equations for ABW warehouse is illustrated in table 9.

Table 13. *Time equations for ABW-picking*

Picking line	25seconds Base time for each picking line
	+ 2seconds * Unit quantity on line
	+ if Identification numbers are read 8seconds * Number of identifications
	+ if units must be protected 40 seconds

If ABW picking line has quantity of two items and both have a serial number that must be recorded, the total modelled time consumption will be 25 + 2*2 + 2*8 + 0 = 45 seconds. And similar if group picking line have one units, which have no serial numbers nor protection is needed, the time consumption will be 150 + 1*8 =158 seconds.

The packing station have basically two optional processes as discussed in previous chapter. Picking could be done straight to cardboard box or to plastic box. If plastic box is used all the material need to be handled to new cardboard box and after that the box can be filled and sealed. Packing station's performance was measured by observation and with efficiency data provided by the warehouse management system.

Time consumption by parcel was measured by both ways of work. When only 12 straight cardboard boxes and 27 plastic box to new cardboard box actions were done the minimal difference in time consumption was clear. The average of straight cardboards was only 2 seconds faster than transferring from box to another. Also the standard deviation was similar between those two methods, with straight cardboard boxes it was 20 seconds compared to 21 seconds with plastic to cardboard transfers. That led to a short decision that there is no need to make difference between those two ways in cost management system.

The variation between packing lines by short measuring was found out not to be great. General observation and discussion with employees were also indicating to that direction. Smaller boxes (which are filled in the packing station with products coming with the plastic boxes) were felt to be faster to fill with sealed air and sealed than larger boxes, which often have more space to fill. This most likely removed the difference between straight boxes and plastic to cardboard boxes. Employees felt that the empty space in one box has some correlation to time usage, but that would be too complex to model comparing the results it would bring. Comparing the volume of the box and the product would have been too complex and inaccurate system.

Besides the factors in previous paragraph employees named only one significant matter affecting the performance at the packing station: how the picking has been done, was the biggest concern among employees at the packing station. If the items are placed to the box on badly manner, the whole box or just a part is in need to be rearranged. The employees felt that this have a noticeable effect on time consumption. That is of course impossible to define from transaction data, and was not seen to happen too often.

All the parcels going true the packing station have only one-time consumption number, creating only one cost that is assigned to all parcel. This was mainly crafted with performance measured with lead to conclusion that average overall time usage of the packing station is exactly two minutes per one parcel. The performance was measured using the total parcel number per day divided by the employee working hours at the packing station.

Outbound area process in its pure form is simple and standard. All the parcels are put on a pallet or in a steel rack or a rolltainer. Pallets are frapped with frapping machine. Pallets coming from the full pallet picking are sometimes also in need of frapping. Final checks are done and all needed shipping documents and stamps are attached (most are already placed in at the picking stage). Finally, all are transported to a truck, which is usually done by the external truck driver.

Process is standard and time consumption have basically no variation that could be assign to certain parcels or pallets. No extra work is done by any mean or could be verified that any product or other dimension is affecting on this process. All parcels have one cost and full pallets (coming from full pallet picking) have one cost. The time consumption was verified by using general performance measures of the outbound area. Basically dividing the used working hours with the parcels and pallet going true. A Pallet was valued to use 10 times more time than a parcel.

All parcels coming from group, fast mover or ABW-picking go true exactly same packing and outbound processes. This meant that those costs could be combined and only one cost could be assign to all those parcels. Since those parcels may contain multiple products and the lowest allocation level is a product, a way to split the cost of one parcel to the products it is containing is needed. Weight of each product number was chosen to be the driver. Volume or plain quantity would also have been relevant alternatives, but the weight was an easy choose since it is also the driver to split transportation cost per parcel.

7. ACTION

In this chapter, the complete model and the path to it from single transaction costs is illustrated. How to implementation was done and how it affected the creation of whole model. The model is also validated and valuated.

7.1 The model

Previous chapter has been talking how individual transactions are valued and cost are computed to those via the time equations and capacity cost rates. In next sub chapter all the transaction cost are taken together and a system to tract and evaluate all of those together is created

The created cost management system is not interested about one single items going true the warehouse, but about slightly bigger picture about whole SKU, product group, business unit, customer or supplier. Single transactions are the bottom line and key to all those. One product goes true the whole warehouse and cost are assigned with four stages. First the inbound activities from a truck to self, second the warehousing time, third picking and at last the packing and outbound area activities. The cost management system is tracking all the transaction made by individual items and combines those to listed dimensions.

The model is providing the drivers how to value those transactions compared to each other. All the resource cost created by the actual cost centers are assigned to the transactions and a single transaction will have its share of the total costs. With those the costs can be assigned to the needed dimensions. SKU is always included to a transaction and with it the is a linkage to product group and manufacturer. Customers are not directly related to inbound and warehousing transactions. The cost created by those are shared to customers, while the cost calculations are done and creating that deviation was not a part of that project. The controllers at company X are doing that.

The way to craft the capacity cost rates and time equations were listed previously and how those create the transaction stamps. The data pool made by the stamps is stored and used to perform the cost calculations

Cost rates from inbound have two separate methods how the rates are calculated. Stored line is the trigger, when a stamp is created to the data base. The storing platform tells which method is used. If stored item is a plastic box the cost of transaction is calculated with followed formula. The numerator in the formula is second and the capacity cost rate is in minutes.

$$\text{The cost for one transaction} = \frac{2{,}5 * \text{line strength } + 51}{60} * 0,X69 + 0,X09$$

If stored line has pallet as platform, it will currently get fixed cost regardless any attributes it has. It is the average time consumed at inbound operations 6 minutes and 45 second and average time at inner transportation 5 and half minutes. Which are both multiplied by the capacity cost factor giving an average cost factor.

The warehousing is computed on nightly bases and it is fixed to one storage location, which can be occupied with one or more SKUs. Cost rates are listed in table 14.

Table 14. *Cost rates for warehousing*

Warehouse type	Cost per working day
AWB	1,0
Manual	9,4
Fast mover	87
Od size	61

These are assigned after each work day and stored to database with the cost rate.

The actual cost center outbound is divided to two section and the cost from those are needed to be synchronized together. All the weighted transportation cost share the same pile of actual cost inside these artificial cost centers. Capacity cost rates are valuing the differences on resource usage between processes. These are illustrated in tables 15 and 16.

Table 15. *Cost from picking.*

	ABW	**Fast mover**	**Direct Parcel**	**Group Picking**	**Whole pallet**
Base	25	30	120	150	210
Quantity	2*PC	1*PC	15*PC	8*PC	
Identifications	8*PC	8*PC	8*PC	8*PC	8*PC
Protection	40	40		40	
Capacity cost rate	0,0XX5	0,0XX6	0,0XX9	0,0XX3	0,0XX5

All the other numbers are part of the time equations and are seconds. The last row is the capacity cost rate per second and the sum from time equation is multiplied by it. That creates the driver from picking activity.

Table 16. *Cost from inbound and outbound*

	ABW	Fast mover	Direct Parcel	Group Picking	Whole pallet
Cardboard box	0,X0	0,X0		0,X0	
Packing	0,X396	0,X96		0,X396	
Outbound	0,X58	0,X58	0, X587	0,X58	0,X622

Cost from packing and outbound on table are straight cost rates. Cost from cardboard box and packing occur only to ABW, FM and group pickings.

These drivers are used to evaluate the transactions inside one actual cost center. The total cost of each actual cost center is divided to all weighted transactions inside it. The actual transaction costs are computed to dimensions. All the transaction occurs to some SKU, which is the base to assign the created cost to dimension.

A SKU comes from one supplier and belongs to one product group, which make all the transactions made by that SKU easy to assign to those dimensions. Customers are a bit more challenging, since one SKU is sold to multiple customers and time scope of the calculations is also a significant factor while assigning cost from

7.2 Implementation

In the second phase of the project with company X, implementation of the cost allocation system was done. Making the theoretical model, created by thesis worker, work in real environment and day to day business life was crucial to whole project. Implementation and how it can be made was taken account all the way from the beginning of the project. The costing model needs to be capable to implement with given resources. With previous criteria, the planning to implement the model was already been done simultaneously while crafting the model. Parameters or stamps form operations should already exist in current data tables or confirmations form IT-specialist and project sponsor were needed that new data tables are possible and reasonable to create. With warehousing costs a totally new data table was created.

The second secondary level research question is directly related to implementation and what kind of system is implemented. The system should be easy to use in day to day life and demand of resources should be on reasonable level while the actual cost assignment is done.

Some alternatives to execute the implementation where found out and evaluated, but the final solution was basically doing the implementation with the resources already in the company X. Other were more outsources ones. Most interesting to the thesis worker, would have been using specific software, which is made to allocate cost by time driven ABC. That would have provided much more freedoms for more complex cost allocations and more precocious time equations and capacity cost rates. On the down side the software was found out to be too complex and expensive to serve only the costs created by the warehouse activities. That would have been more reasonable if cost management from most of company X's departments would have implemented the costing system at once.

The selected solution to implementation was use SQL-database calls from existing data pools and creating one new data pool. A core team of four people were formed to do and coordinate the implementation project:

- Controller
- Thesis worker
- Two It-system specialist

The CFO was still the project owner and the team had backup from finance and logistic operations. The controller was assigned to be the project leader of the implementation and reporting to CFO, was her responsibility.

Implementations team's main task was to create correct reports that will model the cost stamps. Second step was to implement time equation rates to the stamps and final was active the costing system to company's business analytics. Implementation process was divided to four stages. First where outbound, second was warehousing, third was picking and finally sending. This was also the order how the implementation was done. Logical order was not a purpose, but more like a coincidence. First two steps were fast done, but two latest ones were harder and took quite a lot of time to execute. Meantime those were taken account with simplified excel table, which could assign the cost of those operations in some level, but for example all the serial numbers read were not taken account. This temporary way was maybe affecting the implementation of the actual way, since resources are critical and it was easier to postpone the project, while it was somehow working.

Data from inbound and outbound stamps were created using already existing data, but a new data pool to data warehouse was created for warehousing stamps. This meant that warehousing stamps were the only one were historical data was unavailable. That's why it was the most crucial to get up and running, but also a challenging one.

The long list of transactions valued by the drivers is used by the financial controllers of Company X while performing cost allocations. The cost calculations are done afterwards on monthly bases, basically always one to two weeks after the month have ended. Controllers are counting all the transactions intensities together and dividing the cost from actual cost pools with those intensities concerning specific dimensions: SKU (product number), product group, business unit, customer and manufacturer. Each of these dimensions will have 100% of cost of each cost center and the deviation is done with the transaction intensities by different customers, product numbers or manufacturer. This has many similarities with the previous costing system and for example, assigning the cost from inbound to customers is done as in the previous model.

Cost management system needs to be validated. The big picture should be validated as told in sub chapter 3.5 in operational and financial level. Also, other validation tasks were needed during the implementation process. This meant basically data validations. All were not done by thesis worker.

The accuracy of the date provided to the system was crucial. All transaction data, collected to data pools and to cost calculations, was validated. The data must be correct and represent actual transactions at precise accuracy. That was tested and confirmed by IT-specialist and thesis worker was assisting. Some changes to data models were done during the project, but at the end it was confirmed to be correct. No extra or missing transaction were found from final data gatherings. This was done simultaneously with the implementation one phase at time. The collected data was used also to other functions inside the organization and the demand of accuracy was on elevated level.

Warehousing activity was again different. It was the only database created only for this. The model's warehousing database was compared to the amounts of totally stocked items in the month. This was done in SKU level and the controller from Company X was assisting the thesis worker. The monthly total stocking number per SKU were available from ERP-system, where's the new data base was formed based on warehouse management system. Also some manual checks were performed to random and selected locations.

Operational level validation was done by comparing the measured working hours to modelled time consumption at each artificial cost center. This was done already while crafting the drivers and drivers were adjusted base on that. At picking and outbound the total working hours were one of the key information while crafting the drivers. At inbound and storing it was a validation to the drivers based more on operational measures. With the adjustment, the accuracy was found out to be on proficient level. The difference was lower than 5 percent, while comparing the numbers at artificial cost centers.

While this is written automated data capture, using the drivers was not ready with picking, packing and outbound. Lengthy period (more than one day) analyses were left out, with those processes.

Financial level validation was left with smaller inspection. Resource cost were basically pre-assigned and all noted cost were assigned to a cost center or divided to many centers. Financial validation inside the actual cost centers was basically not needed, as Kaplan and Anderson it described, since all the resource cost assigned to actual cost centers are divided by the drivers.

With warehousing costs ABW and manual locations were found to be less costly and fast mover and od-size locations costly like assumed after the process definition. From company management, the high cost created by the fast mover were find out to be satisfying and reasonable, but high cost created by od size was found out to be not satisfying, since od-size products are not practically high movable and some of products, that have to be warehoused there, do not even have a high value. This makes big bulky products expensive to keep in the warehouse and the logistical cost of those can be significant compared to material value in some cases.

7.3 Summary

Although the cost calculations are based on Kaplan and Anderson's time driven activity based costing the actual model is more of a simplification of it. All the transactions will have a certain intensity compared to other transactions in the same general cost center. The intensity levels are calculated with time equations, but the final and overall cost calculation done by the financial controllers of company X. The cost calculations are done afterwards on monthly bases, basically always one to two weeks after the month have ended, like in the study by Everaert's (et al 2008). Controller(s) is (are) counting all the transactions intensities together and dividing the cost from actual cost pools with those intensities concerning specific dimensions: product number, product group, business unit, customer and manufacturer. Each of these dimensions will have 100% of cost of each cost center and the deviation is done with the transaction intensities by different customers, product numbers or manufacturer.

Totally 16 different transactions are measured. Those are divided to 3 actual cost centers, which are divided to artificial cost centers. This is illustrated in figure 10.

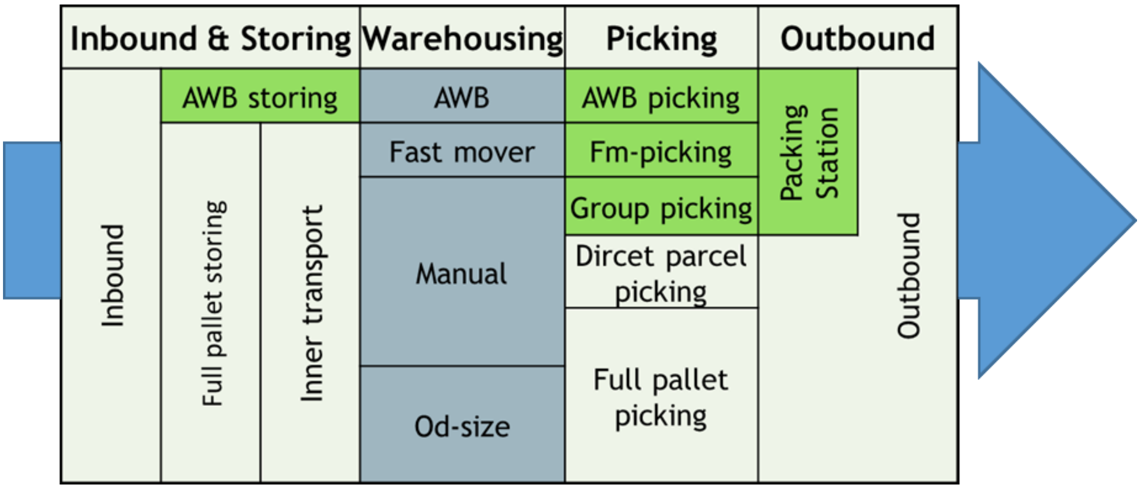


Figure 10. *Sub processes forming the artificial cost centers.*

These 16 measured transactions create the operational link to processes. The artificial and actual cost center create the valid connection to the financial level. Material flow is coming from left to right as the arrow indicates.

Combined usage of actual and artificial cost centers and the fixed drivers to all transactions was not found from literature with TDABC. These were used, since the monthly work load was tried to minimize at the cost of workload while implementing. With the drivers and double cost centers, this was successfully done without costly systems.

Cost centers do not even belong to TDABC, but the process view of creating different capacity cost rates is quite similar. Demeere's (et al 2009) model to create different cost pools was also used as an advantage while allocating resource cost to artificial cost centers. These artificial cost center could have been called as processes to use same terms as Kaplan and Anderson.

All criteria at the end of chapter 4 are filled. TDABC is used as theoretical framework. Calculation are based on measured processes as it was stated at validation and with figure 10. Matching principle is honored via the drives ant parameters while those were created. And finally the implementation was possible, with current resources.

8. CONCLUSIONS

The main purpose of this thesis was to determine and craft valid drives to allocate logistical cost at Company X. It was done through observation and data analysis. This chapter summarizes the main results. The results and the whole study are then assessed as well as the utilized methods are evaluated. Recommendations for further development at Company X and to studies are also given.

8.1 Main results and recommendations for further actions at Company X

Within the project, integrated to this master of science thesis, a base to a cost calculations system was created. The system is providing the drivers to assign all the logistical cost to wanted dimension. The system is based on three actual cost centers, which are divided to artificial cost centers. The sub processes forming the artificial cost centers are illustrated in figure 10 at previous chapter.

The cost calculations are based on process modelling. Processes were modelled both theoretically based on concepts and by observation when processes were up and running. This with validated transaction stamps is grounding the model to be based on actual and real life. With the cost management system, the financial department at Company X could assign the cost to all needed dimensions.

Time driven activity based costing was used as an advance and the model is a sort of variation on it. The key benefits from it occur with transaction cost from inbound and outbound operations. Transactions with different and complex resource usage and work intensity were valued and compared between each other with TDABC. This was effective way and made the final calculations by the controllers easy.

To inbound area and pallet storing was left with poorest accuracy and it is a clear subject for further research. Two different models were illustrated in chapter 5. Neither could make work with the limitations in this project. For further if more accurate cost information is needed those could be researched further. The current situation with full pallet storing is not good and the model is not accurate. This should be updated, if either of the models, to update it, is found out to be usable.

All and all this cost management system needs updates time to time. Dividing all the cost to dimensions by weighted transactions is decreasing the need for updates, since increases or decreases with resource cost are computed in at any case. Process changes would be the biggest factor effecting the accuracy of these calculations.

The ease of use is hard to model. The user of the whole costing tool is the controller at Company. The model needs about one day at her work per each costing period. Her working performance and other task are critical to actual performance in use. So far the model was not fully implemented and the actual full work load was unknown. With the inbound, warehousing and temporary picking and outbound model, the time consumption while performing the cost management calculations was in good level. The controller could perform the cost management analyses in time. Finishing the picking and outbound activities should make the calculations more accurate and the needed manual work would decrease a bit.

8.2 Assessment of the study

Research questions stayed untouched during the project, but duration and even the research methods changed widely. At the beginning of the project the research should have been more simulation orientated. The outcome from the project was matched the needs and specifications agreed with Company X. The research objects are filled and questions have been answered. Notifying the improvement needs at Company X the project has been successful.

The methods to create the drivers was changed and time table was postponed. According to the first plan the drivers should have been ready at same time when the new processes and facilities were implemented to full use. Only the validation and needed changes should be after the start of new processes. Main material for process modelling would have been the process blueprints and specification of machinery and systems providers. Performance changes compared to previous processes, should create the base of the process performance modelling. Comparing the new processes to previous ones. The process modelling and time drivers should have been based on those. The uncertainly was felt to be too great. Almost at the beginning the method was decided to be more observing one and the process analyses must be based to actual measures. This also decreased the work for validation, since the processes are measured.

Generality of the results is strictly constricted. This study was determined to solve a local problem and not to create new generally valid information. The nature of the results is not to be generally valid but to full fill the research questions, which are strictly tied to Company X and its environment. The main result are the drivers that are valuing the transactions occur at distribution center. Those are not generality valid at all, but the model to create those is more valid and could be used to craft transaction based costing drivers.

With the multi method research over processes and cost, whit assumptions, observation, measures, intervention and data analyses the validly of the results in on satisfactory level. Of course, those represent only the processes at the time the model was done. Improvements and other changes will affect the validly of the model.

Costing could have been more accurate if resource cost would have been re calculated after the real usages of each month. With the model the capacity cost rates and transaction cost were fixed with certain transactions. Floating capacity cost rates depending the actual usage of the resources could have been more accurate. On the other hand the sharing of 100 percent of all cost of actual cost center is decreasing the effect of capacity changes.

8.3 Recommendations for further studies

Time-Driven Activity-based costing should be more simple than regular ABC, which is quite generally noted as resource demanding and hard to operate. TDABC might be an easy model to craft and to understand how it works, but the complete system is needs heavy IT and implementation. Countless transactions and transaction parameters are needed to be stored. Could using similar fixes driver pattern help the implementation and usage in more general level?

This thesis created a way to craft cost drivers and a whole cost management system. This thesis is strictly constricted to this specific field and organization. While the method in the study to craft the drivers is successfully applied in this organization and field, could it be possible to expand the validity of the method? Would this way to craft the drivers work in different organization or even different fields? Can this be even more simple way to create a cost management system to organization, which is willing to have the benefits of time-driven ABC, but not willing to pay a lot to a service provider and an IT provider with real TDABC software.

Deeper analysis between output and inputs to run a cost management system would be an appropriate research subject. Many costing methods are resource demanding and that’s why organizations do not use them properly or not at all. All thou the better outputs from costing management can create better business intelligence and better results. Makin costing simple more and more organizations would most likely start to measure their costs in deeper level.

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APPENDIX A: MAIN PROCESS CHART